

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 08-171054

(43)Date of publication of application : 02.07.1996

(51)Int.Cl.

G02B 17/08

(21)Application number : 08-313354

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(22)Date of filing : 16.12.1994

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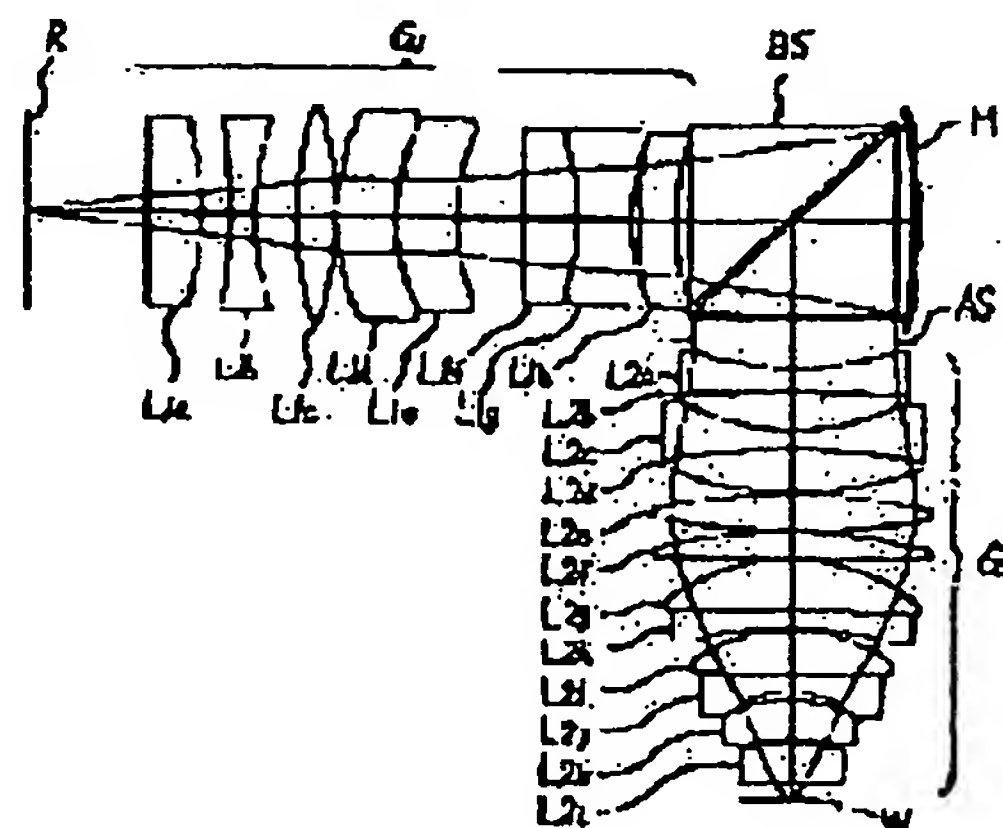
(54) REFLECTION REFRACTION OPTICAL SYSTEM

(57)Abstract:

PURPOSE: To obtain a large numerical aperture on the image side, to secure a sufficient working distance on the image side and to miniaturize a beam splitter by locating the rear principal point of a second lens group closer to the image side than a light entrance surface on the side of the beam splitter of the second lens group and satisfying a specified condition.

CONSTITUTION: A reflection/refraction optical system makes a light beam from a first surface R pass through a first lens group G1 and a beam splitter BS in order, introduces it to a concave mirror M, makes the light beam from the beam splitter BS reflected by the concave mirror M pass through the beam splitter BS and a second lens group G2 in order and introduces it to a second surface W. The rear principal point of the second lens group G2 is located closer to the image side than a light entrance surface on the side of the beam splitter BS and the conditions: $-1 < 1/\beta_M < 0.5$.

$0.85 < L1/f2$ are satisfied, where, β_M : the image forming magnification of the concave mirror M, L1: a distance between the rear principal point and the light entrance surface and f2: the focal distance of the second lens group G2.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's

(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号

特開平8-171054

(43)公開日 平成8年(1996)7月2日

(51)IntCl.
G 0 2 B 17/08

識別記号
A

庁内整理番号

F I

技術表示箇所

審査請求 未請求 請求項の数7 O L (全 12 頁)

(21)出願番号 特願平6-313354

(22)出願日 平成6年(1994)12月16日

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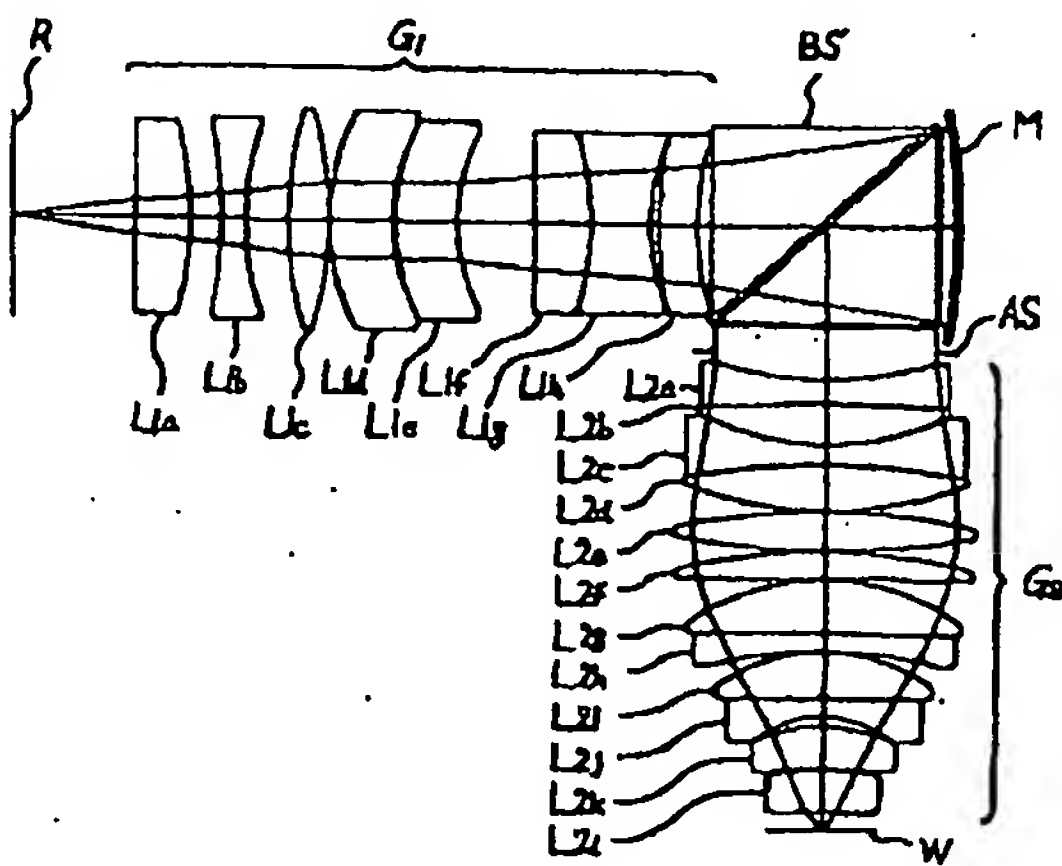
東京都千代田区丸の内3丁目2番3号 株式会社ニコン内

(54) [発明の名称] 反射屈折光学系

(57) [要約]

【目的】 像側における大開口数を達成し、像側作動距離を十分に確保した上でビームスプリッタの小型化を図り、クォーターミクロンの解像を得る。

【構成】 本発明において、第1面Rからの光は、第1レンズ群G₁、ビームスプリッタBS、拡大倍率の凹面鏡M、ビームスプリッタBS及び第2レンズ群G₂の順に通過して第2面W上に達し、第2面W上には第1面Rの縮小像が形成される。本発明は、上述の構成に基づいて凹面鏡Mの結像倍率の好適な範囲と、第2レンズ群G₂の好適な構成とを見出したものである。



【特許請求の範囲】

【請求項1】第1面の縮小像を第2面上に形成する反射屈折光学系において、

第1レンズ群、ビームスプリッタ、拡大倍率を有する凹面鏡及び第2レンズ群を含み、前記第1面からの光を前記第1レンズ群及び前記ビームスプリッタの順に通過させて前記凹面鏡に導くと共に、前記凹面鏡にて反射された前記ビームスプリッタからの光を前記ビームスプリッタ及び前記第2レンズ群の順に通過させて前記第2面に導き、

前記第2レンズ群の後側主点位置は前記第2レンズ群の前記ビームスプリッタ側の光線入射面位置よりも像側に位置し、

以下の条件を満足することを特徴とする反射屈折光学系、

$$-1 < 1/\beta_s < 0.5$$

$$0.85 < L_1/f_2$$

但し、 β_s ：前記凹面鏡の結像倍率、

L_1 ：前記後側主点位置と前記光線入射面との距離、

f_2 ：前記第2レンズ群の焦点距離、

である。

【請求項2】前記反射屈折光学系全体の結像倍率を β とし、前記第2レンズ群の結像倍率を β_s とすると、以下の条件を満足することを特徴とする請求項1記載の反射屈折光学系、

$$-1 < \beta_s/\beta < 1$$

【請求項3】前記ビームスプリッタは、プリズム型ビームスプリッタから構成されることを特徴とする請求項1または2記載の反射屈折光学系、

【請求項4】前記プリズム型ビームスプリッタの前記第2レンズ群側の射出面を含む像側には開口絞りが設けられ、以下の条件を満足することを特徴とする請求項3記載の反射屈折光学系、

$$0.26 < D_1/f_2 < 1.00$$

但し、 D_1 ：前記凹面鏡と前記開口絞りとの間の空気換算距離、

f_2 ：前記凹面鏡の焦点距離、

である。

【請求項5】前記ビームスプリッタの前記第2レンズ群側の射出面と前記第2面との間の空気換算距離を D_2 とし、前記第2レンズ群の焦点距離を f_2 とし、前記反射屈折光学系の前記第2面側における開口数を NA とすると、

以下の条件を満足することを特徴とする請求項4記載の反射屈折光学系、

$$D_2 \cdot NA/f_2 > 0.70$$

【請求項6】以下の条件を満足することを特徴とする請求項4または5記載の反射屈折光学系、

$$(\phi_s/4d_2 \cdot NA)/(f_2 \cdot (NA)^2) < 4$$

但し、 ϕ_s ：前記ビームスプリッタの方向変換面の前記第2レンズ群側の射出面への正射影の面積、

d_2 ：前記反射屈折光学系の前記第2面側における作動距離、

NA ：前記反射屈折光学系の前記第2面側における開口数、

f_2 ：前記第2レンズ群の焦点距離、

である。

【請求項7】前記第1及び第2レンズ群は、少なくとも二種類の異なる材質からなる屈折要素から構成され、前記第1レンズ群は、蛍石からなる負レンズ成分を有し、

前記第2レンズ群は、蛍石からなる正レンズ成分を有することを特徴とする請求項1乃至5のいずれか一項記載の反射屈折光学系、

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、例えば半導体素子、又は液晶表示素子等をフォトリソグラフィ工程で製造する際に使用される投影露光装置用の、縮小投影用の投影光学系に適用して好適な反射屈折縮小光学系に関し、特に光学系の要素として反射系を用いることにより、紫外線波長域でクォーターミクロン単位の解像度を有する反射屈折縮小光学系に関する。

【0002】

【従来の技術】半導体素子等を製造するためのフォトリソグラフィ工程において、フォトマスク又はレチクル（以下、まとめて「レチクル」という）のパターン像を投影光学系を介して例えば1/4乃至1/5程度に縮小して、フォトレジスト等が塗布されたウェハ（又はガラスプレート等）上に露光する投影露光装置が使用されている。半導体素子等の集積度が向上するにつれて、投影露光装置に使用されている投影光学系に要求される解像力は益々高まっている。この要求を満足するために、照明光の波長を短く且つ投影光学系の開口数（ NA ）を大きくする必要が生じている。

【0003】しかしながら、照明光の波長が短くなると、光の吸収によって実用に耐える硝材の種類は限られ、波長が300nm以下になると実用上使える硝材は合成石英と蛍石だけとなる。これにより屈折系だけで投影光学系を構成すると、色収差をはじめ各諸収差補正が困難となる。これに対して反射系は色収差がないため、反射系と屈折系とを組み合わせた所謂反射屈折光学系で縮小投影光学系を構成する技術が提案されている。

【0004】反射系に対する光束の入出力を行うための光路交換用ビームスプリッターを有する反射屈折縮小光学系としては、例えば特開平2-88510号公報、特開平4-235516号公報及び特開平5-72478号公報等に関示されている。ここで、上記公報に関示される反射屈折縮小光学系に含まれている凹面鏡は、すべ

て縮小倍率を持つ収斂鏡であった。

【0005】

【発明が解決しようとする課題】上記の如き従来の反射屈折縮小光学系においては、凹面鏡が縮小倍率を有しているため、凹面鏡よりも像側の光路に配置されるレンズ群の結像倍率が大きなものとなっていた。従って、従来の反射屈折縮小光学系において大きな開口数を得ようとすると、それにほぼ比例してビームスプリッターの口径を大きくする必要がある。これは製造上困難であると共に、製造コストも高くなり過ぎるという不都合がある。そして、凹面鏡が縮小倍率を有しているため、ビームスプリッターから像面までの距離が短くなり、像側における作動距離を十分に確保することが困難である。また、ビームスプリッターの方向変換面に入射する光束の光線の角度が各々違うことによる、結像性能の劣化も避けることが出来ない。

【0008】そこで、本発明は、像側において大きな開口数を達成し、かつ十分な像側作動距離を確保し、さらにビームスプリッターの小型化を図ることができるクォーターミクロン単位の解像をもつ反射屈折光学系を提供することを目的とする。

【0007】

【課題を解決するための手段】上述の目的を達成するために、本発明による反射屈折光学系は、例えば図1に示す如く、第1面Rの縮小像を第2面W上に形成する反射屈折光学系であって、第1レンズ群G₁、ビームスプリッタBS、拡大倍率を有する凹面鏡M及び第2レンズ群G₂を含むように構成される。そして、該反射屈折光学系は、第1面Rからの光を第1レンズ群G₁及びビームスプリッタBSの順に通過させて凹面鏡Mに導くと共に、凹面鏡Mにて反射されたビームスプリッタBSからの光をビームスプリッタBS及び第2レンズ群G₂の順に通過させて第2面Wに導き、第2レンズ群G₂の後側主点位置は第2レンズ群G₂のビームスプリッタBS側の光線入射面位置よりも像側に位置し、以下の条件を満足するように構成される。

【0008】

$$-1 < 1/\beta_1 < 0.5 \quad \dots (1)$$

$$0.85 < L_1/f_1 \quad \dots (2)$$

但し、 β_1 ：凹面鏡Mの結像倍率、

L_1 ：後側主点位置と光線入射面との距離、

f_1 ：第2レンズ群G₂の焦点距離、

である。

【0009】

【作用】上述の構成の如き本発明においては、凹面鏡Mが拡大倍率を有するため、第2レンズ群G₂に大きな正屈折力を持たせることができる。この構成により、ビームスプリッタBSの大型化を図ることなく、像側において大きな開口数を達成し、かつ十分な可動距離を確保することができる。

【0010】そして、本発明においては、ビームスプリッタBS内を通過する光束中の各々の光線の方向変換面への入射角の角度差を小さくできるため、ビームスプリッタBSによる結像性能の劣化を防ぐことができる利点を有する。次に、条件式について詳述する。条件式

(1)は凹面鏡Mの好適な結像倍率の範囲についての条件である。この条件式の下限を超えると、第2レンズ群G₂に大きな正屈折力を持たせることが困難となり、像側において大きな開口数を達成するためにはビームスプリッタBS自体の大型化を図る必要が生じる。このときには、ビームスプリッタBSの製造が困難となり、また製造コストの上昇を招く。そして、ビームスプリッタBSと像面との間の距離を十分に確保できなくなるため、十分な作動距離を確保することが困難になる。さらに、凹面鏡MからビームスプリッタBSの方向変換面に向かう光束が収斂光束となるため、この光束中の光線において入射角の角度差が大きくなり、結像性能を低下を招く。なお、この条件式(1)の下限を -0.8 とし、 $-0.8 < 1/\beta_1$ とすることが好ましい。

【0011】また、条件式(1)の上限を超えると、凹面鏡Mが担っている正の屈折力が小さくなるため、収差補正が困難となる。なお、さらに収差補正を良好とするためには、条件式(1)の上限を 0.2 とし、 $1/\beta_1 < 0.2$ とすることが好ましい。条件式(2)は第2レンズ群G₂の好適な構成についての条件である。ここで、第2レンズ群G₂が条件式(2)を満足しない場合、すなわち条件式(2)の下限を超える場合には、ビームスプリッタBSの径の大型化を免れることができないばかりか、像側における作動距離を実用上十分に確保できなくなるため好ましくない。なお、上記条件式

(2)の上限を 8.0 とし、 $L_1/f_1 < 8.0$ とすることが望ましい。この上限値を超える場合には、大きな開口数を得ようとすると、収差補正が困難になるばかりでなく、光学系の全長が長くなり過ぎ、半導体製造装置に用いる投影光学系として不適当である。なお、本発明において、さらに大きな開口数を得ることとビームスプリッタBSの小型化とを考慮すると、条件式(2)の下限値を 1.35 とし、 $1.35 < L_1/f_1$ とすることが望ましい。

【0012】なお、本発明におけるビームスプリッタBSは、偏光方向によって光を分離する偏光ビームスプリッタであることが好ましい。また、このときには、ビームスプリッタBSと凹面鏡Mとの間の光路中には $\lambda/4$ 板が配置される。また、本発明においては、第2レンズ群G₂の結像倍率 β_2 は、本発明の反射屈折光学系全体の結像倍率を β とすると、以下の条件を満足することが好ましい。

【0013】

$$-1 < \beta_2/\beta < 1 \quad \dots (3)$$

条件式(3)は、第2レンズ群G₂の結像倍率の好適な

範囲についての条件である。この条件式(3)の下限を超えると、ビームスプリッタBSの口径の大型化を伴うことなく、大きな開口数を得ることができなくなるため好ましくない。また、条件式(3)の上限を超えると、本発明の反射屈折光学系における屈折光学要素(例えば第1レンズ群G₁、第2レンズ群G₂)が担う屈折力が大きくなり過ぎ、すなわち反射光学要素(凹面鏡M)の効果が小さくなり、収差補正上において困難を来すため好ましくない。

【0014】本発明においては、ビームスプリッタBSをプリズム型ビームスプリッタとすることが好ましい。そして、開口絞りASは、このプリズム型ビームスプリッタの射出面を含む像側に設けられることが好ましい。ここで、開口絞りASは、以下の条件式を満足するように配置されることが好ましい。

$$0.28 < D_1 / f_2 < 1.00 \quad \dots (4)$$

但し、D₁：凹面鏡Mと開口絞りASとの間の空気換算距離、

f₂：凹面鏡Mの焦点距離、

である。

【0015】ここで、空気換算距離とは、それぞれの媒体の各々の距離と屈折率との商の和として定義される縮小距離であり、空気換算距離をd_tとし、媒体の各々の距離をd_iとし、各々の媒体の屈折率をn_iとすると、下式にて表される。

【0016】

【数1】

$$d_t = \sum_i \frac{d_i}{n_i}$$

【0017】条件式(4)は、開口絞りASの配置について好適な範囲を定める条件式である。この条件式の下限を超えると、開口絞りASが凹面鏡Mに近づき過ぎる、または凹面鏡Mの焦点距離が長くなり過ぎる。この*

$$(\phi_1^{1/2} - 4 d_1 \cdot NA) / (f_1 \cdot (NA)^2) < 4 \quad \dots (6)$$

但し、φ₁：ビームスプリッタBSの方向変換面の第2レンズ群G₂側の射出面への正射影の面積、

d₁：反射屈折光学系の第2面W側における作動距離、

NA：反射屈折光学系の第2面W側における開口数、

f₁：第2レンズ群G₂の焦点距離、

である。

【0020】条件式(8)は、像側開口数、像側作動距離及びビームスプリッターの口径に対する第2レンズ群G₂の好適な焦点距離の範囲を定めるための条件式である。この条件式(8)を満足しない場合には、製造上において困難となるため好ましくない。また、ビームスプリッタBSの方向変換面上に薄膜を設ける場合やビームスプリッタBSに入/4板を設ける場合においては、ここでの波面収差の発生量が無視できなくなり像の劣化が著しくなるため好ましくない。なお、製造上の容易性を増し、かつ結像性能の向上を図るためには、この条件式

*ときには、ビームスプリッタBSの小型化を図ることが困難となり、また方向変換面に入射する光線の入射角の角度差を小さくすることが困難となるため好ましくない。ここで、本発明の反射屈折光学系において、上述の条件式(1)および(3)を満足している場合、上記条件式(4)の下限を超えときには、実用上において十分な像側作動距離を得ることが不可能となるばかりでなく、製造上において開口絞りの配置が困難となるため好ましくない。一方、条件式(4)の上限を超えると、軸外光束の収差、特にコマ収差の補正が困難となるため好ましくない。

【0018】また、本発明の反射屈折光学系は、ビームスプリッタBSの第2レンズ群G₂側の射出面と第2面Wとの間の空気換算距離をD₁とし、第2レンズ群G₂の焦点距離をf₂とし、反射屈折光学系の第2面W側における開口数をNAとすると、以下の条件を満足することが好ましい。

$$D_1 \cdot NA / f_2 > 0.70 \quad \dots (5)$$

条件式(5)はビームスプリッターと像面との好適な間隔についての条件式である。この条件式(5)を満足しないと、実用上十分な像側作動距離を保つ場合に、第2レンズ群G₂のためのスペースが小さくなり、第2レンズ群G₂を構成する屈折光学素子の枚数に制限が生じ、収差補正が困難となるため好ましくない。また、条件式(5)を満足しない場合には、上記条件式(3)を満足するように第2レンズ群G₂を構成することが困難となるため好ましくない。なお、大きな像側開口数を達成し、かつ十分な像側作動距離を確保しつつビームスプリッタの小型化を図るためには、条件式(5)における上限を1.0とし、D₁・NA/f₂ < 1.0とすることが望ましい。

【0018】また、本発明においては、以下の条件式(8)を満足するように構成されることが望ましい。

$$(\phi_1^{1/2} - 4 d_1 \cdot NA) / (f_1 \cdot (NA)^2) < 4 \quad \dots (6)$$

(8)の上限を3.5とし、(φ₁^{1/2} - 4 d₁・NA) / (f₁・(NA)²) < 3.5とすることが望ましい。

【0021】なお、本発明による反射屈折光学系において、300nm以下の波長においてクォーターミクロン単位の解像を満足させつつ色収差を補正するためには、第1レンズ群G₁及び第2レンズ群G₂を少なくとも二種類の異なる材質からなる屈折要素で構成することが好ましい。このとき、第1レンズ群G₁は蛍石からなる負レンズ成分を有し、かつ第2レンズ群は蛍石からなる正レンズ成分を有するように構成されることが望ましい。

【0022】この構成を満足する場合には、蛍石からなる負レンズ成分を有する第1レンズ群G₁によって倍率色収差を補正することが可能となり、蛍石からなる正レンズ成分を有する第2レンズ群G₂によって軸上色収差を補正することができる。また、本発明においては、凹

面鏡Mの倍率を上記条件(1)を満足するように構成しているため、ビームスプリッタBSと第2面Wとの間に配置される第2レンズ群G₂のためのスペースを十分に確保できる。従って、各レンズ群の屈折要素を上述の如く構成すれば、300nm以下の波長においてクォーターミクロン単位の解像を満足しつつ色収差を補正することが可能となる。

【0023】尚、本発明においては、ビームスプリッタと第2レンズ群との間の光束がアフォーカルな光束とすることが望ましい。また、本発明においては、ビームスプリッタBSと凹面鏡Mとの間に、収差補正のためのレンズ群を設けても良い。

【0024】

【実施例】以下、図面を参照して本発明による各実施例を説明する。図1は、本発明の第1実施例にかかる反射屈折光学系の光学構成を示す光路図である。図1において、図示なき照明光学系は、例えばArFエキシマレーザの照明光によって、所定のパターンが設けられたレチクルRを照明する。このレチクルRからの光は、第1レンズ群G₁を通過した後、ビームスプリッタBSの方向変換面を透過し、凹面反射鏡Mにて反射され、再びビームスプリッタBSに入射する。凹面反射鏡Mからの光は、ビームスプリッタBSの方向変換面で反射された後に、ビームスプリッタBSの射出面側に設けられた開口絞りASを通過して、第2レンズ群G₂を通過し、ウェハW上に達する。このウェハW上には、レチクルRの縮小像が形成される。

【0025】ここで、本実施例においては、ビームスプリッタBSは、互いに接合された2つの直角プリズムから構成されている。そして、一方の直角プリズムの斜面上には薄膜が蒸着されている。本実施例では、ビームスプリッタBSの接合面上の薄膜が第1レンズ群G₁からの光を透過させ、かつ凹面鏡Mからの光を反射させる機能を有する。

【0026】次に、図1を参照して第1実施例における各レンズ群のレンズ構成を説明する。第1レンズ群G₁は、物体側から順に、ビームスプリッタBS側により強い凸面を向けた両凸形状の正レンズ成分L_{1a}と、両凹形状の負レンズ成分L_{1b}と、両凸形状の正レンズ成分L_{1c}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1d}と、同じく物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1e}と、物体側に凹面を向けたメニスカス形状の正レンズ成分L_{1f}と、両凹形状の負レンズ成分L_{1g}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1h}とから構成される。

$$d_0 = 94.539$$

	r	d	硝材
1	-5313.040	42.330	SiO ₂
2	-329.118	23.191	
3	-454.958	18.854	CaF ₂

*【0027】また、第2レンズ群G₂は、開口絞りAS側から順に、両凹形状の負レンズ成分L_{2a}と、両凸形状の正レンズ成分L_{2b}と、両凹形状の負レンズ成分L_{2c}と、両凸形状の正レンズ成分L_{2d}と、両凸形状の正レンズ成分L_{2e}と、開口絞りAS側により強い凸面を向けた両凸形状の正レンズ成分L_{2f}と、同じく開口絞りAS側により強い凸面を向けた両凸形状の正レンズ成分L_{2g}と、開口絞りAS側に凸面を向けたメニスカス形状の負レンズ成分L_{2h}と、開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2i}と、開口絞りAS側に凸面を向けたメニスカス形状の負レンズ成分L_{2j}と、開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2k}と、同じく開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2l}とから構成される。

【0028】以下の表1に本実施例の諸元の値が掲げられる。本実施例において、全系の倍率は1/4倍(縮小)であり、ウェハW側の開口数NAは0.8であり、ウェハW側における作動距離は15.0mmである。そして、本実施例の反射屈折光学系のウェハW上の露光領域を表す平面図である図2に示す如く、第1実施例の反射屈折光学系は、ウェハW上における光軸Axからの像高が15.3mmまでの範囲において30mm×6mmのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタBSは、170mm×170mm×190mmの直方体形状である。

【0029】また、表1においては、物体面としてのレチクルRのパターン形成面に相当する第1面から像面としてのウェハW面に相当する第2面へ向かう順序で各面の曲率半径r、面間隔dおよび硝材を示している。表1中において、各面の曲率半径rの符号は、レチクルRと凹面鏡Mとの間ではレチクルR側に凸面を向ける場合を正としており、ビームスプリッタBSとウェハWの間ではビームスプリッタBS側に凸面を向ける場合を正としている。また、面間隔dの符号は、凹面鏡MからビームスプリッタBSの方向変換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF₂は蛍石、SiO₂は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長(ArFレーザの波長: $\lambda = 193.4\text{nm}$)における屈折率は以下の通りである。

石英ガラス: 1.56019

蛍石: 1.50138

【0030】

【表1】(第1実施例)

*

9				
4	272.492	31.123		
5	338.834	31.042	SiO ₂	
6	-344.186	0.500		
7	229.022	45.000	SiO ₂	
8	184.586	2.298		
9	208.542	45.000	SiO ₂	
10	1732.582	56.174		
11	-4435.970	42.860	SiO ₂	
12	-244.757	0.500		
13	-288.840	45.000	CaF ₂	
14	233.444	5.342		
15	433.000	29.121	SiO ₂	
16	268.594	10.042		
17	0.000	170.000	SiO ₂	ビームスプリッタBS
18	0.000	10.000		
19	-623.184	-10.000		凹面反射鏡M
20	0.000	-85.000	SiO ₂	
21	0.000	85.000	SiO ₂	方向変換面
22	0.000	20.000		
23	0.000	22.917		開口絞りAS
24	-246.212	19.407	SiO ₂	
25	1018.290	0.657		
26	1228.970	32.523	CaF ₂	
27	-190.064	0.500		
28	-191.929	15.000	SiO ₂	
29	424.920	1.933		
30	503.632	37.933	CaF ₂	
31	-260.380	0.500		
32	441.375	32.753	CaF ₂	
33	-563.177	0.500		
34	378.243	23.321	CaF ₂	
35	-13558.170	0.500		
36	152.386	44.866	CaF ₂	
37	3098.000	0.500		
38	2231.920	15.006	SiO ₂	
39	296.582	0.533		
40	123.151	38.469	CaF ₂	
41	7856.190	0.815		
42	7240.660	15.000	SiO ₂	
43	74.423	7.394		
44	103.429	35.012	CaF ₂	
45	292.945	1.711		
46	192.719	34.643	SiO ₂	
47	1452.820	15.000		

以下に第1実施例における条件対応値を示す。

(1) $l/\beta_s = -0.062$

(2) $L_1/f_s = 1.842$

(3) $\beta_1/\beta = -0.10$

(4) $D_1/f_s = 0.45$

(5) $D_1 \cdot NA/f_s = 1.37$

(6) $(\phi_s^{1/2} - 4d_s \cdot NA)/(f_s \cdot (NA)^{1/2}) = 3.03$

図3に第1実施例の横収差図を示す。ここで、図3(a)は像高10割(像高15.3mm)における横収差図であり、図3(b)は像高5割(像高7.65mm)における横収差図であり、図3(c)は像高0割(光軸上:像高

0.0mm)における横収差図である。なお、各横収差図において、実線は基準波長($\lambda = 193.4\text{nm}$)における収差曲線を表し、点線は波長 $\lambda = 193.5\text{nm}$ における収差曲線、一点鎖線は波長 $\lambda = 193.45\text{nm}$ における収差曲線、破線は $\lambda = 193.35\text{nm}$ における収差曲線、二点鎖線は波長 $\lambda = 193.3\text{nm}$ における収差曲線をそれぞれ表す。図3に示す各横収差図より、本実施例による反射屈折光学系は、 $NA = 0.8$ という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に $193.4\text{nm} \pm 0.1\text{nm}$ での色収差補正がなされており、優れた結像性能を有していることが分かる。次に図4を参照して本発明による第2実施例を説明する。図4は、本発明の第2実施例による反射屈折光学系の構成を示す光路図である。

【0031】図4の反射屈折光学系の基本的な構成は、図1に示す第1実施例の反射屈折光学系とほぼ同じであるため、ここでは説明を省略し、各レンズ群のレンズ構成についてのみ説明する。図4において、第1レンズ群G₁は、物体側から順に、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1a}と、両凸形状の正レンズ成分L_{1b}と、両凸形状の正レンズ成分L_{1c}と、両凹形状の負レンズ成分L_{1d}と、物体側に凹面を向けたメニスカス形状の正レンズ成分L_{1e}と、両凹形状の負レンズ成分L_{1f}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1g}とから構成される。

【0032】また、第2レンズ群G₂は、開口絞りAS側から順に、両凹形状の負レンズ成分L_{2a}と、両凸形状の正レンズ成分L_{2b}と、両凹形状の負レンズ成分L_{2c}と、両凸形状の正レンズ成分L_{2d}と、同じく両凸形状の正レンズ成分L_{2e}と、開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2f}と、開口絞りAS側により強い凸面を向けた両凸形状の正レンズ成分L_{2g}と、開口絞りAS側に凸面を向けたメニスカス形状の負レンズ成分L_{2h}と、開口絞りAS側に凸面を向けたメニスカ

*ス形状の正レンズ成分L_{2i}と、ウェハW側により強い凹面を向けた両凹形状の負レンズ成分L_{2j}と、開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2k}と、同じく開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L_{2l}とから構成される。以下の表2に本実施例の諸元の値が掲げる。本実施例においては上記第1実施例と同様に、全系の倍率は1/4倍(縮小)であり、ウェハW側の開口数NAは0.6であり、ウェハW側における作動距離は15.0mmである。そして、本実施例の反射屈折光学系は、上記第1実施例と同様に、ウェハW上における光軸Axからの像高が15.3mmまでの範囲において30mm×6mmのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタBSは、170mm×170mm×190mmの直方体形状である。

【0033】また、表2においては、物体面としてのレチクルRのパターン形成面に相当する第1面から像面としてのウェハW面に相当する第2面へ向かう順序で各面の曲率半径r、面間隔dおよび硝材を示している。表2中において、各面の曲率半径rの符号は、レチクルRと凹面鏡Mとの間ではレチクルR側に凸面を向ける場合を正としており、ビームスプリッタBSとウェハWの間ではビームスプリッタBS側に凸面を向ける場合を正としている。また、面間隔dの符号は、凹面鏡MからビームスプリッタBSの方向変換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF₂は蛍石、SiO₂は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長(ArFレーザの波長： $\lambda = 193.4\text{nm}$)における屈折率は以下の通りである。

石英ガラス：1.56019
蛍石：1.50138

【0034】
【表2】【第2実施例】

$d_0 = 111.403$

	r	d	硝材
1	5471.605	15.000	CaF ₂
2	272.290	2.678	
3	277.567	31.750	SiO ₂
4	-278.590	0.500	
5	307.964	38.658	SiO ₂
6	-321.548	0.500	
7	-307.926	28.172	CaF ₂
8	185.540	116.871	
9	-6054.190	45.000	SiO ₂
10	-326.561	3.925	
11	-437.618	18.547	CaF ₂
12	429.454	3.774	
13	791.303	28.999	CaF ₂
14	197.545	13.348	

13			14	
15	0.000	170.000	SiO ₂	ビームスプリッタBS
16	0.000	10.000		
17	-600.094	-10.000		凹面反射鏡M
18	0.000	-85.000	SiO ₂	
19	0.000	85.000	SiO ₂	方向変換面
20	0.000	5.000		
21	0.000	18.267		開口絞りAS
22	-228.968	15.000	SiO ₂	
23	602.629	1.000		
24	596.556	39.120	CaF ₂	
25	-193.759	0.500		
26	-198.735	15.599	SiO ₂	
27	414.383	1.371		
28	466.129	43.827	CaF ₂	
29	-250.352	0.500		
30	607.920	26.660	CaF ₂	
31	-570.532	0.500		
32	319.703	24.752	CaF ₂	
33	5248.170	0.500		
34	150.926	44.958	CaF ₂	
35	-11154.640	0.500		
36	6931.942	15.000	SiO ₂	
37	324.944	0.500		
38	123.172	38.693	CaF ₂	
39	27743.950	0.506		
40	-22043.850	15.000	SiO ₂	
41	73.840	8.552		
42	103.200	33.698	CaF ₂	
43	346.408	1.818		
44	217.213	33.291	SiO ₂	
45	1371.742	15.000		

以下に第2実施例における条件対応値を示す。

- (1) $1/\beta_s = -0.077$
 (2) $L_1/f_1 = 1.924$
 (3) $\beta_s/\beta = -0.13$
 (4) $D_1/f_s = 0.41$
 (5) $D_1 \cdot NA/f_1 = 1.31$
 (6) $(\phi_s^{1/2} - 4d_s \cdot NA)/(f_1 \cdot (NA)^{1/2}) = 3.09$

図5に第2実施例の横収差図を示す。ここで、図5(a)は像高10割(像高15.3mm)における横収差図であり、図5(b)は像高5割(像高7.65mm)における横収差図であり、図5(c)は像高0割(光軸上:像高0.0mm)における横収差図である。なお、各横収差図において、実線は基準波長($\lambda = 193.4\text{nm}$)における収差曲線を表し、点線は波長 $\lambda = 193.5\text{nm}$ における収差曲線、一点鎖線は波長 $\lambda = 193.45\text{nm}$ における収差曲線、破線は $\lambda = 193.35\text{nm}$ における収差曲線、二点鎖線は波長 $\lambda = 193.3\text{nm}$ における収差曲線をそれぞれ表す。図5に示す各横収差図より、本実施例による反射屈折光学系

は、 $NA = 0.8$ という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に193.4nm \pm 0.1nmでの色収差補正がなされており、優れた結像性能を有していることが分かる。次に図6を参照して本発明による第3実施例を説明する。図6は、本発明の第2実施例による反射屈折光学系の構成を示す光路図である。

【0035】図6の反射屈折光学系の基本的な構成は、図1に示す第1実施例の反射屈折光学系とほぼ同じであるため、ここでは説明を省略し、各レンズ群のレンズ構成についてのみ説明する。図6において、第1レンズ群G₁は、物体側から順に、ビームスプリッタBS側に強い凸面を向けた両凸形状の正レンズ成分L_{1a}と、両凹形状の負レンズ成分L_{1b}と、両凸形状の正レンズ成分L_{1c}と、物体側に凸面を向けたメニスカス形状の負レンズ成分L_{1d}と、物体側に凸面を向けたメニスカス形状の正レンズ成分L_{1e}と、物体側に凹面を向けたメニスカス形状の正レンズ成分L_{1f}と、両凹形状の負レンズ成分L_{1g}と、物体側に凸面を向けたメニスカス形状の負レンズ成

分し1hとから構成される。

【0038】また、第2レンズ群G₂は、開口絞りAS側から順に、両凹形状の負レンズ成分L2aと、像側に強い凸面を向けた両凸形状の正レンズ成分L2bと、両凹形状の負レンズ成分L2cと、像側に強い凸面を向けた両凸形状の正レンズ成分L2dと、開口絞りAS側に強い凸面を向けた両凸形状の正レンズ成分L2eと、同じく開口絞りAS側に強い凸面を向けた両凸形状の正レンズ成分L2fと、同じく開口絞りAS側に強い凸面を向けた両凸形状の正レンズ成分L2gと、像側に強い凹面を向けた両凹形状の負レンズ成分L2hと、開口絞りAS側に強い凸面を向けた両凸形状の正レンズ成分L2iと、開口絞りAS側に凸面を向けたメニスカス形状の負レンズ成分L2jと、開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L2kと、同じく開口絞りAS側に凸面を向けたメニスカス形状の正レンズ成分L2lとから構成される。

【0037】以下の表3に本実施例の諸元の値が掲げられる。本実施例においては上記第1実施例と同様に、全系の倍率は1/4倍（縮小）であり、ウェハW側の開口数NAは0.6であり、ウェハW側における作動距離は15.0mmである。そして、本実施例の反射屈折光学系は、上記第1実施例と同様に、ウェハW上における光軸*

$$d_0 = 95.384$$

	r	d	硝材
1	1566.352	33.601	SiO ₂
2	-258.445	42.686	
3	-303.358	35.000	CaF ₂
4	254.513	39.688	
5	408.129	35.000	SiO ₂
6	-292.562	0.500	
7	238.980	28.106	SiO ₂
8	177.718	35.520	
9	236.585	35.000	SiO ₂
10	258.786	35.249	
11	-1574.830	35.000	SiO ₂
12	-195.650	0.500	
13	-220.429	25.000	CaF ₂
14	228.713	7.071	
15	380.419	35.000	SiO ₂
16	274.848	10.847	
17	0.000	170.000	SiO ₂
18	0.000	10.000	
19	-644.053	-10.000	
20	0.000	-85.000	SiO ₂
21	0.000	85.000	SiO ₂
22	0.000	10.000	
23	0.000	16.475	
24	-240.493	27.541	SiO ₂
25	609.289	0.500	

* Axからの像高が15.3mmまでの範囲において30mm×8mmのスリット状の露光領域を有する。また、本実施例におけるビームスプリッタBSは、170mm×170mm×190mmの直方体形状である。

【0038】また、表3においては、物体面としてのレチクルRのパターン形成面に相当する第1面から像面としてのウェハW面に相当する第2面へ向かう順序で各面の曲率半径r、面間隔dおよび硝材を示している。表3中において、各面の曲率半径rの符号は、レチクルRと凹面鏡Mの間ではレチクルR側に凸面を向ける場合を正としており、ビームスプリッタBSとウェハWの間ではビームスプリッタBS側に凸面を向ける場合を正としている。また、面間隔dの符号は、凹面鏡MからビームスプリッタBSの方向交換面に到る光路では負にとり、他の光路では正にとる。そして、硝材として、CaF₂は蛍石、SiO₂は石英ガラスをそれぞれ表す。ここで、石英ガラスおよび蛍石の使用基準波長（ArFレーザの波長： $\lambda = 193.4\text{nm}$ ）における屈折率は以下の通りである。石英ガラス：1.58019 蛍石

：1.50138

【0039】

【表3】【第3実施例】

ビームスプリッタBS

凹面反射鏡M

方向交換面

開口絞りAS

26	648.361	39.879	CaF ₂
27	-161.540	0.500	
28	-161.204	15.000	SiO ₂
29	432.174	2.340	
30	513.767	39.791	CaF ₂
31	-245.896	0.500	
32	397.672	35.000	CaF ₂
33	-1373.400	0.500	
34	350.822	28.205	CaF ₂
35	-1504.430	0.500	
36	152.096	44.808	CaF ₂
37	-3015.120	0.546	
38	-3831.930	15.302	SiO ₂
39	292.927	0.657	
40	122.588	34.934	CaF ₂
41	1224.997	0.539	
42	1218.161	15.188	SiO ₂
43	74.562	8.605	
44	108.074	35.000	SiO ₂
45	377.013	1.406	
46	259.877	35.000	SiO ₂
47	767.722	15.000	

以下に第3実施例における条件対応値を示す。

- (1) $1/\beta_s = -0.116$
 (2) $L_1/f_1 = 2.053$
 (3) $\beta_1/\beta = -0.18$
 (4) $D_1/f_s = 0.40$
 (5) $D_1 \cdot NA/f_1 = 1.37$
 (6) $(\phi_1^{1/4} - 4d_1 \cdot NA)/(f_1 \cdot (NA)^{1/4}) = 3.07$

図7に第3実施例の横収差図を示す。ここで、図7(a)は像高10割(像高15.3mm)における横収差図であり、図7(b)は像高5割(像高7.65mm)における横収差図であり、図7(c)は像高0割(光軸上:像高0.0mm)における横収差図である。なお、各横収差図において、実線は基準波長($\lambda = 193.4\text{nm}$)における収差曲線を表し、点線は波長 $\lambda = 193.5\text{nm}$ における収差曲線、一点鎖線は波長 $\lambda = 193.45\text{nm}$ における収差曲線、破線は $\lambda = 193.35\text{nm}$ における収差曲線、二点鎖線は波長 $\lambda = 193.3\text{nm}$ における収差曲線をそれぞれ表す。図7に示す各横収差図より、本実施例による反射屈折光学系は、 $NA = 0.8$ という非常に大きな開口数を達成しているにも拘わらず、良好に収差が補正され、特に193.4nm \pm 0.1nmでの色収差補正がなされており、優れた結像性能を有していることが分かる。

【0040】尚、上述の各実施例において、ビームスプリッタBSの方向変換面は、例えば誘電体多層膜からなる偏光分離面であることが好ましい。このときには、ビームスプリッタBSの凹面鏡Mに対向する面上に $\lambda/4$ 板を設ける。また、上記誘電体多層膜において、収差が

発生する場合には、ビームスプリッタBSの第1レンズ群G₁に対向する面、凹面鏡M側に対向する面及び第2レンズ群G₂に対向する面のうちの少なくとも一面に誘電体多層膜にて発生する収差を打ち消す薄膜を設けることが好ましい。このような薄膜としては、例えば厚さまたは屈折率が部分的に異なる構成のものを用いれば良い。

30 【0041】また、上述の各実施例においては、第1レンズ群G₁から凹面鏡Mに向かう光束がビームスプリッタBSの方向変換面を透過し、かつ凹面鏡Mから第2レンズ群G₂へ向かう光束がビームスプリッタBSの方向変換面にて反射する構成であるが、第1レンズ群G₁からの光束をビームスプリッタBSの方向変換面にて反射させて凹面鏡Mへ導き、かつ凹面鏡Mからの光束をビームスプリッタBSの方向変換面を透過させて第2レンズ群G₂へ導く構成としても、光学設計上においては等価なものである。

40 【0042】

【発明の効果】以上の通り本発明によれば、像側において大きな開口数を達成し、かつ十分な像側作動距離を確保し、さらにビームスプリッタの小型化を図ることができ、クォーターミクロン単位の解像を達成することができる。

【図面の簡単な説明】

【図1】本発明の第1実施例による反射屈折光学系の光路図である。

50 【図2】第1実施例の反射屈折光学系の露光領域を示す平面図である。

【図3】第1実施例の横収差図であり、図3(a)は像高10割における横収差図であり、図3(b)は像高5割における横収差図であり、図3(c)は像高0割における横収差図である。

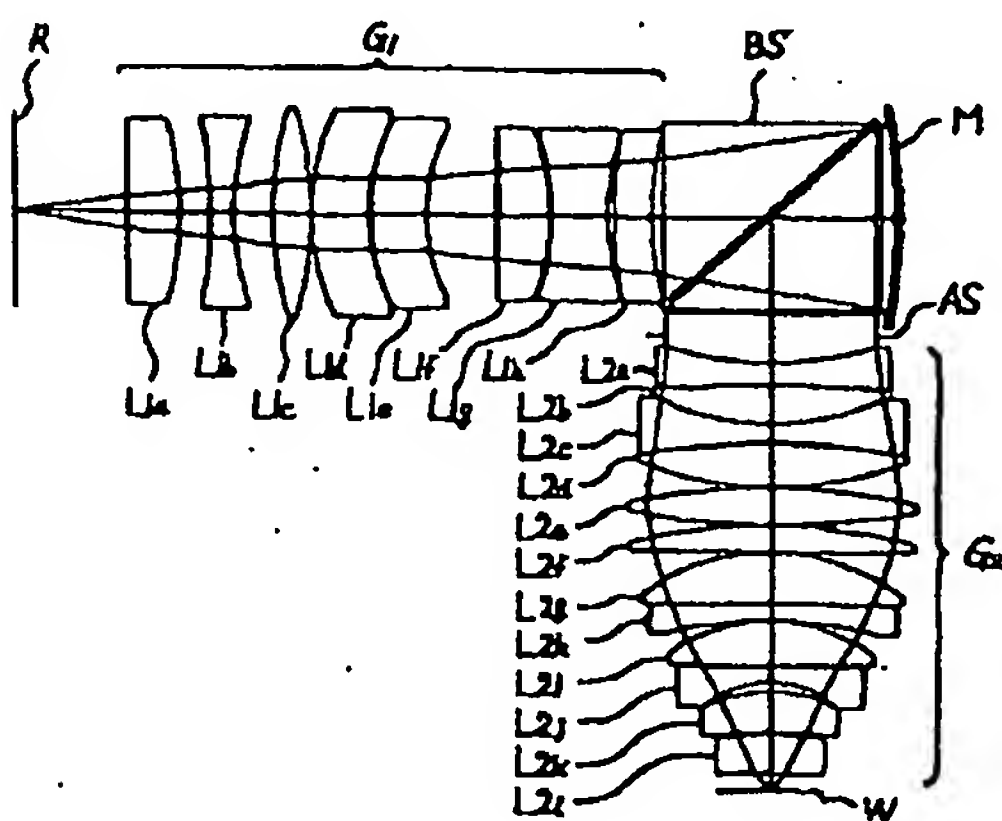
【図4】本発明の第2実施例による反射屈折光学系の光路図である。

【図5】第2実施例の横収差図であり、図5(a)は像高10割における横収差図であり、図5(b)は像高5割における横収差図であり、図5(c)は像高0割における横収差図である。

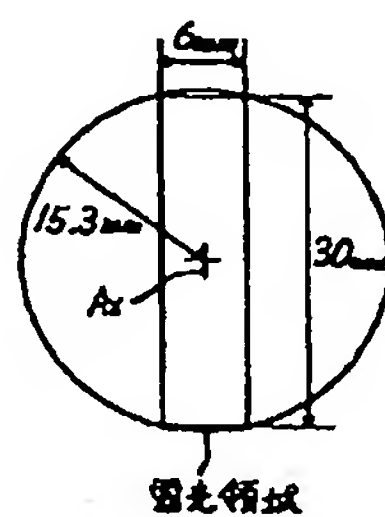
【図6】本発明の第3実施例による反射屈折光学系の光路図である。

*

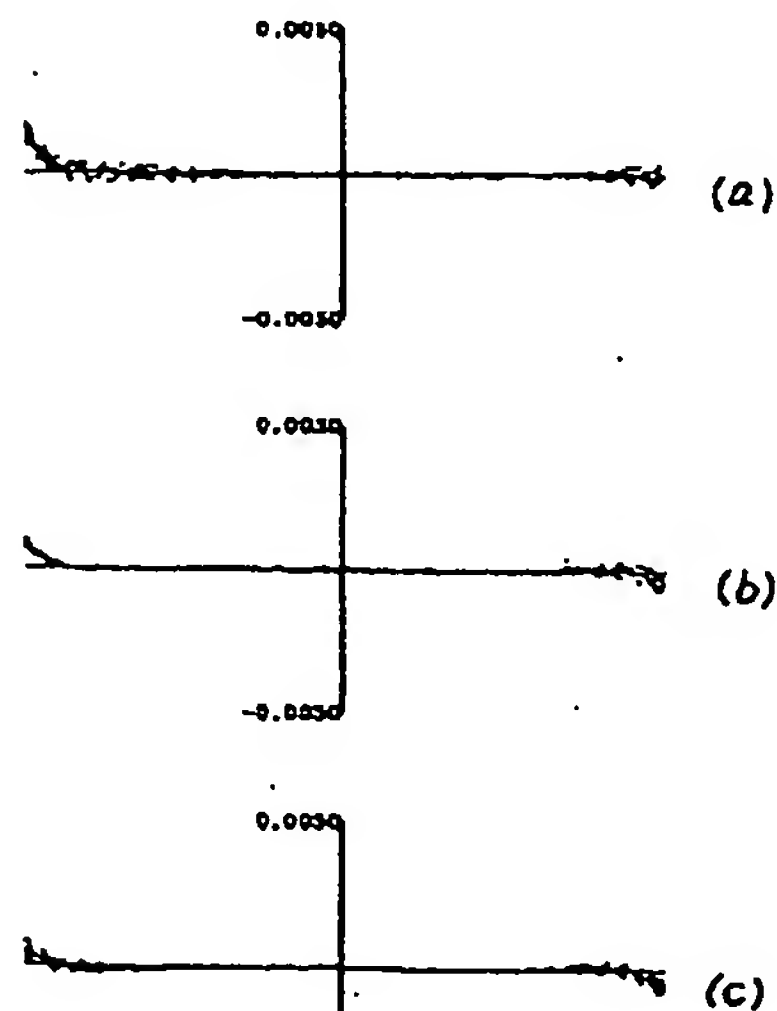
【図1】



【図2】



【図3】



..... 173.5mm
 173.65mm
 173.8mm
 173.95mm
 174.1mm

*【図7】第3実施例の横収差図であり、図7(a)は像高10割における横収差図であり、図7(b)は像高5割における横収差図であり、図7(c)は像高0割における横収差図である。

【符号の説明】

G₁ ... 第1レンズ群、

G₂ ... 第2レンズ群、

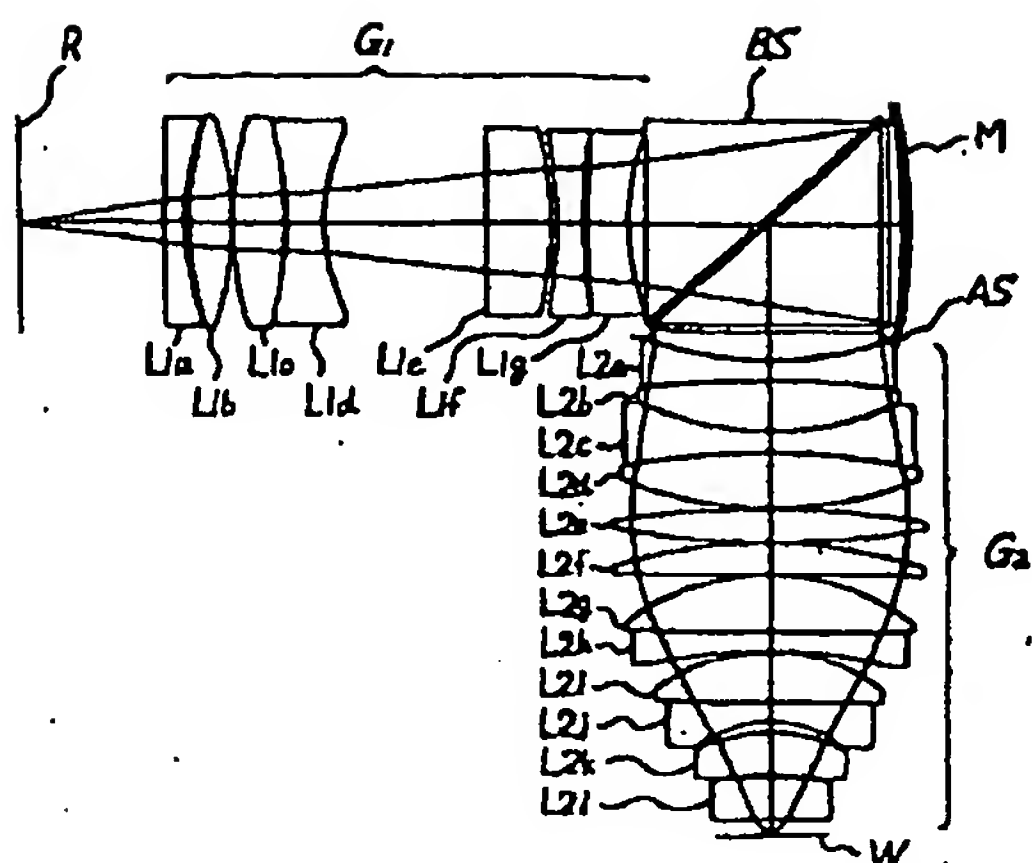
BS ... ビームスプリッタ、

AS ... 開口絞り、

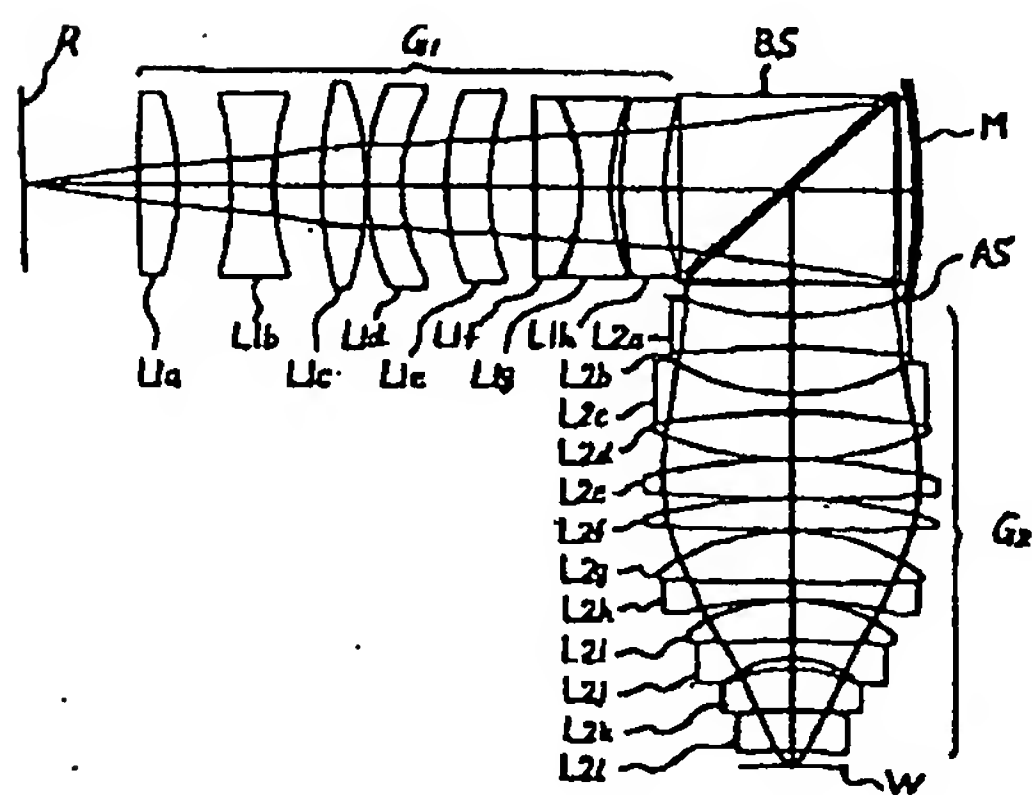
10 R ... レチクル(第1面)、

W ... ウェハ(第2面)、

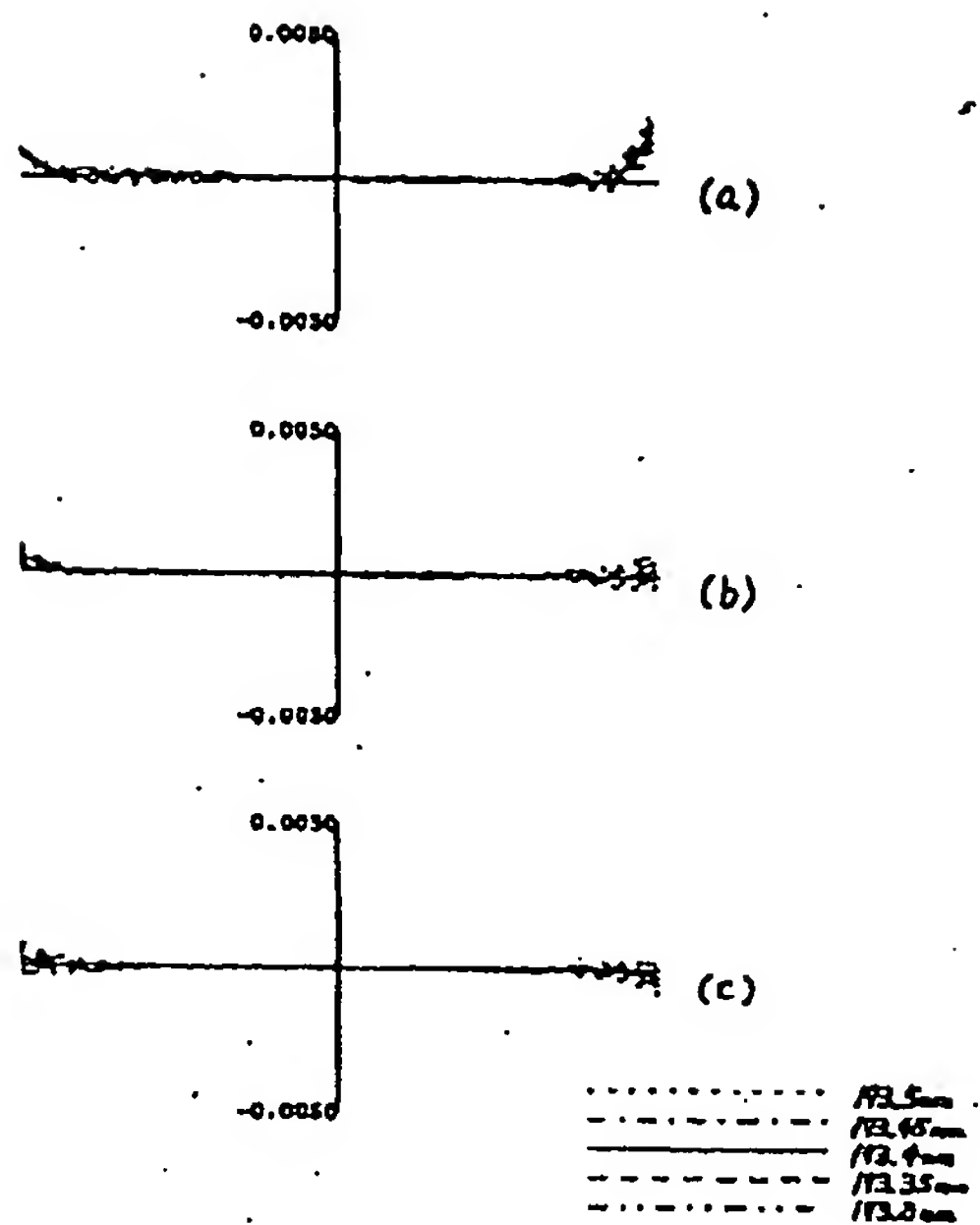
【図4】



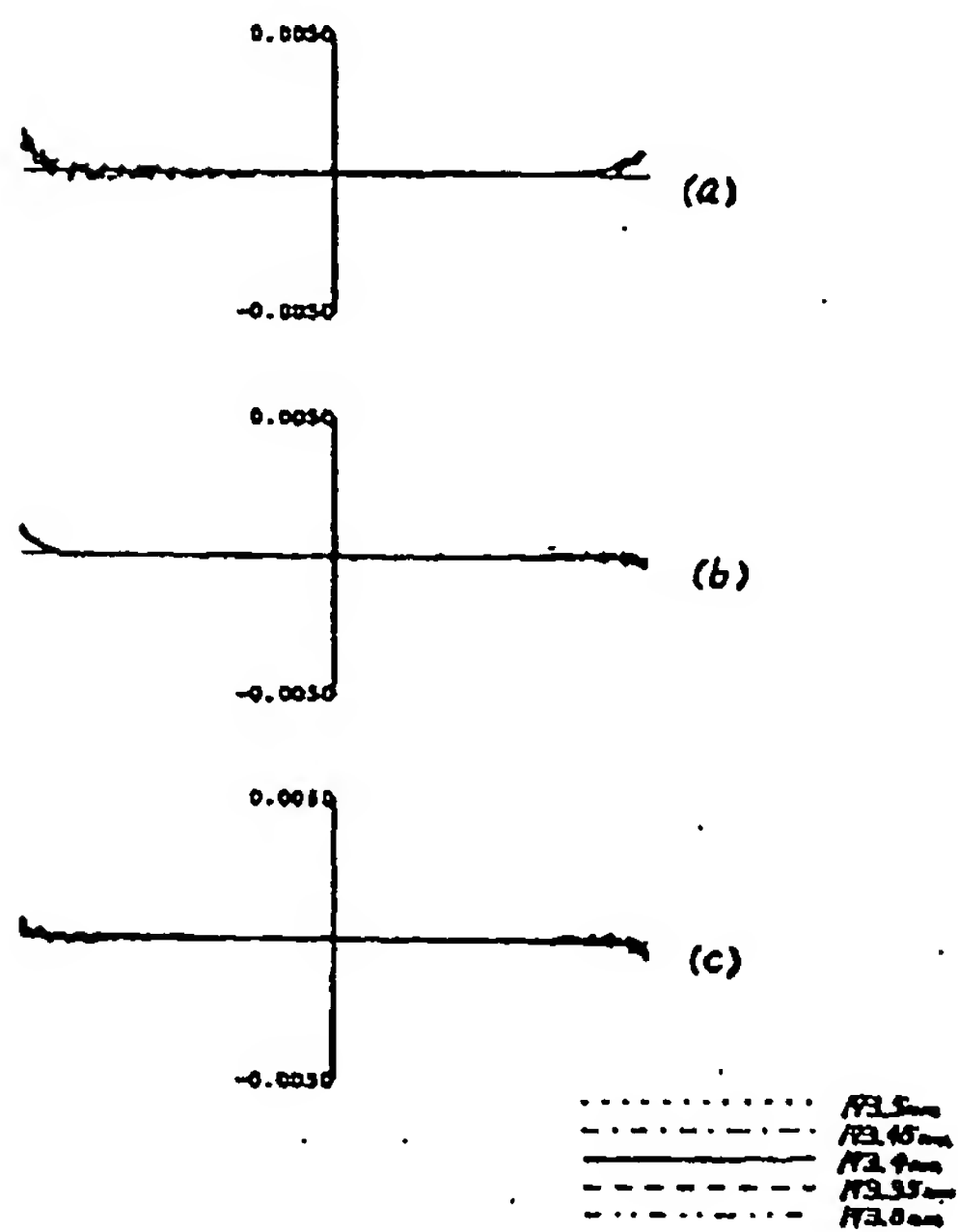
【図6】



【図5】



【図7】



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CLAIMS

[Claim(s)]

[Claim 1] In the cata-dioptric system which forms the contraction image of the 1st page on the 2nd page The 1: lens group, While passing said light from the 1st page in order of said 1st lens group and said beam splitter and leading to said concave mirror including the concave mirror and the 2nd lens group which have a beam splitter and magnifying power Pass the light from said beam splitter reflected with said concave mirror in order of said beam splitter and said 2nd lens group, and it leads to said 2nd page. A backside [said 2nd lens group] principal point location is cata-dioptric system characterized by being located in an image side and satisfying the following conditions rather than the beam-of-light plane-of-incidence location by the side of said beam splitter of said 2nd lens group.

- 1 -- < -- $1/\beta M < 0.50.85$ -- < -- $L1 / f2$, however βM : The image formation scale factor of said concave mirror, and $L1$: The distance of said backside principal point location and said beam-of-light plane of incidence, and $f2$: the focal distance of said 2nd lens group -- it comes out.

[Claim 2] the image formation scale factor of said whole cata-dioptric system -- β -- carrying out -- the image formation scale factor of said 2nd lens group -- $\beta 2$ -- cata-dioptric system according to claim 1 characterized by satisfying the following conditions when carrying out.

- 1 -- < -- $\beta 2 / \beta < 1$ -- [Claim 3] Said beam splitter is cata-dioptric system according to claim 1 or 2 characterized by consisting of prism mold beam splitters.

[Claim 4] Cata-dioptric system according to claim 3 characterized by preparing an aperture diaphragm in an image side including the injection side by the side of said 2nd lens group of said prism mold beam splitter, and satisfying the following conditions.

$0.26 < D1/fM < 1.00$, however $D1$: The air scaled distance between said concave mirrors and said aperture diaphragms, and fM : the focal distance of said concave mirror -- it comes out.

[Claim 5] It is the air scaled distance between the injection side by the side of said 2nd lens group of said beam splitter, and said 2nd page $D2$ It carries out and is the focal distance of said 2nd lens group $f2$ Cata-dioptric system according to claim 4 characterized by satisfying the following conditions when carrying out and setting numerical aperture by the side of said 2nd page of said cata-dioptric system to NA .

$D2$ and $NA/f2 > 0.70$ -- [Claim 6] Cata-dioptric system according to claim 4 or 5 characterized by satisfying the following conditions.

$(\phi B / 2 - dW \text{ and } NA) / (f2 \text{ and } 2) < 4$ -- however ϕB : Area of the orthographic projection to the injection side by the side of said 2nd lens group of the directional change side of said beam splitter, dW : -- the working distance by the side of said 2nd page of said cata-dioptric system, and NA : -- the numerical aperture by the side of said 2nd page of said cata-dioptric system, and $f2$: the focal distance of said 2nd lens group -- it comes out.

[Claim 7] It is the cata-dioptric system of five claim 1 characterized by for said 1st and 2nd lens group consisting of refraction elements which consist of at least two kinds of different quality of the materials, for said 1st lens group having the negative lens component which consists of fluorite, and said 2nd lens group having the positive lens component which consists of fluorite thru/or given in any 1 term.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]**[0001]**

[Industrial Application] It is related with the reflective refraction contraction optical system which has the resolution of a quarter micron unit in an ultraviolet-rays wavelength region by applying to the projection optics for contraction projection for the projection aligners used in case this invention is manufactured by the semiconductor device and ** manufactures a liquid crystal display component etc. at a photolithography process, and using a reflective system especially as an element of optical system about suitable reflective refraction contraction optical system.

[0002]

[Description of the Prior Art] In the photolithography process for manufacturing a semiconductor device etc., a photo mask or the pattern image of a reticle (collectively henceforth a "reticle") is reduced to 1/4 thru/or about 1/5 through projection optics, and the projection aligner exposed on the wafer (** is a glass plate etc.) with which the photoresist etc. was applied is used. The resolution required of the projection optics currently used for the projection aligner is increasing increasingly as degrees of integration, such as a semiconductor device, improve. In order to satisfy this demand, it will be necessary to enlarge numerical aperture (N.A.) of projection optics short [wavelength / of the illumination light].

[0003] However, if the wavelength of the illumination light becomes short, the class of ** material which is equal to practical use with the absorption of light will be restricted, and if wavelength is set to 300nm or less, the ** material which can be used practically will serve as only synthetic quartz and fluorite. If this constitutes projection optics only from refractive media, chromatic aberration will be begun and each ***** amendment will become difficult. On the other hand, since a reflective system does not have chromatic aberration, the technique which constitutes contraction projection optics from so-called cata-dioptric system which combined reflective system and refractive media is proposed.

[0004] As reflective refraction contraction optical system which has a beam splitter for optical-path conversion for outputting and inputting the flux of light over a reflective system, it is indicated by JP,2-66510,A, JP,4-235516,A, JP,5-72478,A, etc., for example. All the concave mirrors contained in the reflective refraction contraction optical system indicated by the above-mentioned official report here were convergence mirrors with a contraction scale factor.

[0005]

[Problem(s) to be Solved by the Invention] In the conventional reflective refraction contraction optical system like the above, since the concave mirror had the contraction scale factor, it had become what has the bigger image formation scale factor of the lens group arranged at the optical path by the side of an image than a concave mirror. Therefore, if it is going to obtain a big numerical aperture in the conventional reflective refraction contraction optical system, it is necessary to enlarge aperture of a beam splitter in proportion [almost] to it. Having un-arranged [that a manufacturing cost also becomes high too much] while a manufacture top is difficult for this. And since the concave mirror has the contraction scale factor, it is difficult for the distance from a beam splitter to the image surface to become short, and to fully secure the working distance by the side of an image. Moreover, degradation of the image formation engine performance by the include angle of the beam of light of the flux of light which carries out incidence to the directional change side of a beam splitter being respectively different is also unavoidable.

[0006] Then, a big numerical aperture is attained, and this invention secures sufficient image side working

distance to an image side, and aims at offering cata-dioptric system with resolving of a quarter micron unit which can attain the miniaturization of a beam splitter further.

[0007]

[Means for Solving the Problem] The cata-dioptric system according to this invention in order to attain the above-mentioned purpose is the concave mirror M and the 2nd lens group G2 which are the cata-dioptric system which forms the contraction image of the 1st page R on the 2nd page W, and have the 1st lens group (a beam splitter BS, and magnifying power as shown in drawing 1 . It is constituted so that it may contain. And this cata-dioptric system is the 1st lens group G1 about the light from the 1st page R. And while making it pass in order of a beam splitter BS and leading to a concave mirror M They are a beam splitter BS and the 2nd lens group G2 about the light from the beam splitter BS reflected with the concave mirror M. Make it pass in order and it leads to the 2nd page W. The 2nd lens group G2 A backside principal point location is the 2nd lens group G2. It is located in an image side rather than the beam-of-light plane-of-incidence location by the side of a beam splitter BS, and it is constituted so that the following conditions may be satisfied.

[0008]

- $1 < 1/\beta_M < 0.5$ (1)

$0.85 < L1 / f2$ (2)

however, β_M : The image formation scale factor of a concave mirror M, and $L1$: The distance of a backside principal point location and beam-of-light plane of incidence, and $f2$: The 2nd lens group G2 a focal distance it comes out.

[0009]

[Function] Since a concave mirror M has magnifying power in this invention like an above-mentioned configuration, it is the 2nd lens group G2. Forward big refractive power can be given. By this configuration, without attaining enlargement of a beam splitter BS, big numerical aperture can be attained and sufficient movable distance can be secured to an image side.

[0010] And in this invention, since angular difference of the angle of incidence to the directional change side each beam of light in the flux of light which passes through the inside of a beam splitter BS can be made small it has the advantage which can prevent degradation of the image formation engine performance by the beam splitter BS. Next, conditional expression is explained in full detail. Conditional expression (1) is the condition about the range of the suitable image formation scale factor of a concave mirror M. When the minimum of this conditional expression is exceeded, it is the 2nd lens group G2. It becomes difficult to give forward big refractive power, and in order to attain a big numerical aperture to an image side, it will be necessary to attain enlargement of beam splitter BS itself. At this time, manufacture of a beam splitter BS becomes difficult, and the rise of a manufacturing cost is caused. And since it becomes impossible to fully secure the distance between a beam splitter BS and the image surface, it becomes difficult to secure sufficient working distance. Furthermore, since the flux of light which goes to the directional change side of a beam splitter BS turns into the convergence flux of light from a concave mirror M, in the beam of light in this flux of light, the angular difference of an incident angle becomes large and causes a fall for the image formation engine performance. In addition, the minimum of this conditional expression (1) is set to -0.8, and it is $-0.8 < 1/\beta_M$. Carrying out is desirable.

[0011] Moreover, if the upper limit of conditional expression (1) is exceeded, since the forward refractive power which the concave mirror M is bearing will become small, aberration amendment becomes difficult. In addition, in order to make aberration amendment good further, it is desirable to set the upper limit of conditional expression (1) to 0.2, and to be referred to as $1/\beta_M < 0.2$. Conditional expression (2) is the 2nd lens group G2. They are the conditions about a suitable configuration. Here, it is the 2nd lens group G2. When not satisfying conditional expression (2) (i.e., when exceeding the minimum of conditional expression (2)), since it becomes impossible to fully secure practically the working distance by the side of about [that enlargement of the path of a beam splitter BS cannot be escaped], and an image, it is not desirable. In addition, it is desirable to set the upper limit of the above-mentioned conditional expression (2) to 6.0, and to be referred to as $L1/f2 < 6.0$. If it is going to obtain big numerical aperture when exceeding this upper limit, it is unsuitable as projection optics aberration amendment not only becomes difficult, but used for semiconductor fabrication machines and equipment by the overall length of optical system becoming long too much. In addition, when obtaining a still bigger numerical aperture and the miniaturization of a beam splitter BS are taken into

consideration in this invention, the lower limit of conditional expression (2) is set to 1.35, and it is $1.35 < L1 / f2$. Carrying out is desirable.

[0012] In addition, as for the beam splitter BS in this invention, it is desirable that it is the polarization beam splitter which separates light according to the polarization direction. Moreover, at this time, $\lambda/4$ plate is arranged in the optical path between a beam splitter BS and a concave mirror M. Moreover, it sets to this invention and is the 2nd lens group G2. Image formation scale factor β_2 . When setting the image formation scale factor of the whole cata-dioptric system of this invention to β , it is desirable to satisfy the following conditions.

[0013]

- $1 < \beta_2 / \beta < 1$ -- (3)

Conditional expression (3) is the 2nd lens group G2. They are the conditions about the range where an image formation scale factor is suitable. Without being accompanied by enlargement of the aperture of a beam splitter BS, if the minimum of this conditional expression (3) is exceeded, since it becomes impossible to obtain big numerical aperture, it is not desirable. Moreover, if the upper limit of conditional expression (3) is exceeded, it is not desirable in order for the refractive power which the dioptrics element (for example, the 1st lens group G and the 2nd lens group G2) in the cata-dioptric system of this invention bears to become large too much, namely, for the effectiveness of a reflected light study element (concave mirror M) to become small and to cause difficulty on aberration amendment.

[0014] In this invention, it is desirable to make a beam splitter BS into a prism mold beam splitter. And as for aperture diaphragm AS, it is desirable to be prepared in an image side including the injection side of this prism mold beam splitter. Here, as for aperture-diaphragm AS, it is desirable to be arranged so that the following conditional expression may be satisfied.

$0.26 < D1 / fM < 1.00$ -- (4)

D1 [however,] : The air scaled distance between a concave mirror M and aperture-diaphragm AS, and fM : the focal distance of a concave mirror M -- it comes out.

[0015] Here, air scaled distance is a contraction distance defined as the sum of the quotient of each distance and refractive index of each medium, and is dt about air scaled distance. It carries out and is d_i about each distance of a medium. It carries out and is n_i about the refractive index of each medium. It is expressed with a bottom type when carrying out.

[0016]

[Equation 1]

$$dt = \sum_i \frac{d_i}{n_i}$$

[0017] Conditional expression (4) is conditional expression by which the range suitable about arrangement of aperture-diaphragm AS is provided. If the minimum of this conditional expression is exceeded, aperture-diaphragm AS will approach a concave mirror M too much, or the focal distance of a concave mirror M will become long too much. Since it becomes difficult to make small angular difference of the incident angle of the beam of light which it becomes difficult at this time to attain the miniaturization of a beam splitter BS, and carries out incidence to a directional change side, it is not desirable. When above-mentioned conditional expression (1) and (3) are satisfied and the minimum of the above-mentioned conditional expression (4) is exceeded in the cata-dioptric system of this invention here, since it not only becomes impossible to acquire sufficient image side working distance on practical use, but arrangement of an aperture diaphragm becomes difficult on manufacture, it is not desirable. On the other hand, if the upper limit of conditional expression (4) is exceeded, since amendment of the aberration of an axial outdoor daylight bundle, especially comatic aberration becomes difficult, it is not desirable.

[0018] Moreover, the cata-dioptric system of this invention is the air scaled distance between the injection side by the side of the 2nd lens group G2 of a beam splitter BS, and the 2nd page W D2. It carries out and is the 2nd lens group G2. It is a focal distance $f2$. When carrying out and setting numerical aperture by the side of the 2nd page W of cata-dioptric system to NA, it is desirable to satisfy the following conditions.

D2 and $NA / f2 > 0.70$ -- (5)

Conditional expression (5) is the conditional expression about suitable spacing of a beam splitter and the image surface. If this conditional expression (5) is not satisfied, when maintaining practically sufficient image side

working distance, it is the 2nd lens group G2. The tooth space of a sake becomes small and it is the 2nd lens group G2. Since a limit arises in the number of sheets of the dioptrics component to constitute and aberration amendment becomes difficult, it is not desirable. Moreover, it is the 2nd lens group G2 so that it may satisfy the above-mentioned conditional expression (3), in not satisfying conditional expression (5). Since constituting becomes difficult, it is not desirable. In addition, in order to attain the miniaturization of a beam splitter, attaining a big image side numerical aperture, and securing sufficient image side working distance, it is desirable to set the upper limit in conditional expression (5) to 1.0, and to consider as $D2 \text{ and } NA/f2 < 1.0$.

[0019] Moreover, in this invention, it is desirable to be constituted so that the following conditional expression (6) may be satisfied.

$(\phi B \cdot 1/2 \cdot dW \text{ and } NA)/(f2 \text{ and } 2) < 4 \text{ -- (6)}$

however, ϕB : The 2nd lens group G2 of the directional change side of a beam splitter BS The area of the orthographic projection to a near injection side, and dW : The working distance by the side of the 2nd page W of cata-dioptric system, the numerical aperture by the side of the 2nd page W of NA:cata-dioptric system, and $f2$: The 2nd lens group G2 a focal distance -- it comes out.

[0020] Conditional expression (6) is an image side numerical aperture, the image side working distance, and the 2nd lens group G2 to the aperture of a beam splitter. It is the conditional expression for appointing the range of a suitable focal distance. When not satisfying this conditional expression (6), since it becomes difficult on manufacture, it is not desirable. Moreover, since it becomes impossible to disregard the yield of wave aberration here and degradation of an image becomes remarkable when forming $\lambda/4$ plate in the case where a thin film is prepared on the directional change side of a beam splitter BS, or a beam splitter BS, it is not desirable. In addition, in order to aim at improvement in the increase of ease and the image formation engine performance on manufacture, it is desirable to set the upper limit of this conditional expression (6) to 3.5, and to be referred to as $(\phi B \cdot 1/2 \cdot dW \text{ and } NA)/(f2 \text{ and } 2) < 3.5$.

[0021] In addition, in order to amend chromatic aberration in the cata-dioptric system by this invention, satisfying resolving of a quarter micron unit in the wavelength of 300nm or less, it is the 1st lens group G1. As for the 2nd lens group G2 It is desirable to constitute from a refraction element which consists of at least two kinds of different quality of the materials. At this time, it is the 1st lens group G1. It has the negative lens component which consists of fluorite, and, as for the 2nd lens group, it is desirable to be constituted so that it may have the positive lens component which consists of fluorite.

[0022] The 1st lens group G1 which has the negative lens component which consists of fluorite in satisfying this configuration The 2nd lens group G2 which has the positive lens component which becomes possible [amending the chromatic aberration of magnification], and consists of fluorite Axial overtone aberration can be amended. Moreover, the 2nd lens group G2 arranged between a beam splitter BS and the 2nd page W since the scale factor of a concave mirror M is constituted in this invention so that the above-mentioned conditions (1) may be satisfied The tooth space of a sake is fully securable. Therefore, if the refraction element of each lens group is constituted like ****, it will become possible to amend chromatic aberration, satisfying resolving of a quarter micron unit in the wavelength of 300nm or less.

[0023] In addition, in this invention, it is desirable for the flux of light between a beam splitter and the 2nd lens group to consider as the afocal flux of light. Moreover, in this invention, the lens group for aberration amendment may be prepared between a beam splitter BS and a concave mirror M.

[0024]

[Example] Hereafter, each example by this invention is explained with reference to a drawing. Drawing 1 is the optical-path Fig. showing the optical configuration of the cata-dioptric system concerning the 1st example of this invention. In drawing 1, the illumination-light study system without illustration illuminates the reticle R in which the predetermined pattern was prepared by the illumination light of for example, ArF excimer laser. The light from this reticle R is the 1st lens group G1. After passing, the directional change side of a beam splitter B is penetrated, it is reflected by Lieberkuhn M, and incidence is again carried out to a beam splitter BS. The light from Lieberkuhn M passes aperture-diaphragm AS prepared in the injection side side of a beam splitter BS after being reflected in respect of directional change of a beam splitter BS, and is the 2nd lens group G2. It passes and reaches on Wafer W. The contraction image of Reticle R is formed on this wafer W.

[0025] Here, in this example, the beam splitter BS consists of two joined rectangular prisms. And the thin film is vapor-deposited on the slant face of one rectangular prism. this example -- the thin film on the plane of

composition of a beam splitter BS -- the 1st lens group G1 from -- it has the function to make light penetrate and to reflect the light from a concave mirror M.

[0026] Next, with reference to drawing 1, the lens configuration of each lens group in the 1st example is explained. The 1st lens group G1 Positive lens component L1a of both the convex configuration which turns the strong convex by the beam splitter BS side sequentially from the body side, Negative lens component L1b of both the concave configuration, and positive lens component L1c of both the convex configuration, Negative lens component L1d of the meniscus configuration where the convex was turned to the body side, and negative lens component L1e of a meniscus configuration which similarly turned the convex to the body side, It consists of positive lens component L1f of the meniscus configuration where the concave surface was turned to the body side, negative lens component L1g of both the concave configuration, and negative lens component L1h of the meniscus configuration where the convex was turned to the body side.

[0027] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration, and negative lens component L2c of both the concave configuration, Positive lens component L2d of both the convex configuration, and positive lens component L2e of both the convex configuration, Positive lens component L2f of both the convex configuration where the strong convex was turned by the aperture-diaphragm AS side, Positive lens component L2g of both the convex configuration where the strong convex was similarly turned by the aperture-diaphragm AS side, Negative lens component L2h of the meniscus configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2i of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, It consists of negative lens component L2j of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l of the meniscus configuration where the convex was similarly turned to the aperture-diaphragm AS side.

[0028] The value of the item of this example hangs up over following Table 1. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this, and the numerical aperture NA by the side of Wafer W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And as shown in drawing 2 which is a top view showing the exposure field on the wafer W of the cata-dioptric system of this example, the image quantity from the optical axis [cata-dioptric system / of the 1st example] Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm. Moreover, the beam splitter BS in this example is a 170mmx170mmx190mm rectangular parallelepiped configuration.

[0029] Moreover, in Table 1, the sequence of going to the 2nd page equivalent to the Wth page of the wafer a the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r, Spacing d, and the ** material of each side. All over Table 1, between Reticle and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optical paths for negative according to the optical path which reaches the directional change side of a beam splitter B from a concave mirror M. And it is CaF2 as ** material. Fluorite and SiO2 Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of Ar laser: $\lambda = 193.4\text{nm}$) of quartz glass and fluorite is as follows.

Quartz glass: 1.56019 fluorite : 1.50138 [0030]

[Table 1] [The 1st example]

d0 = 94.539 r d ** material 1 -5313.040 42.330 SiO2 2 - 329.118 23.191 3 - 454.958 18.864 CaF2 4 272.492 31.123 5 338.834 31.042 SiO2 6 - 344.186 0.500 7 229.022 45.000 SiO2 8 184.586 2.298 9 208.542 45.000 SiO2 10 1732.582 56.174 11 -4435.970 42.860 SiO2 12 - 244.757 0.50013 -288.840 45.000 CaF2 14 233.444 5.342 15 433.000 29.121 SiO2 16 268.594 10.042 17 0.000 170.000 SiO2 Beam splitter BS 18 0.000 10.000 1 623.184 -10.000 The lieberkuhn M20 0.000-85.000 SiO2 21 0.000 85.000 SiO2 Directional change side 22 0.000 20.000 23 0.000 22.917 Aperture-diaphragm AS 24 - 246.212 19.407 SiO2 25 1018.290 0.657 26 1228.970 32.523 CaF2 27 -190.064 0.500 28 - 191.929 15.000 SiO2 29 424.920 1.933 30 503.632 37.933 CaF2 31 260.380 0.500 32 441.375 32.753 CaF2 33 -563.177 0.500 34 378.243 23.321 CaF2 35 -13558.170 0.500 36 152.386 44.866 CaF2 37 3098.000 0.500 38 2231.920 15.006 SiO2 39 296.582 0.533 40 123.151 38.469 CaF2

417856.190 0.815 42 7240. 660 15.000SiO2 43 74.4237.394 44 103.42935.012CaF2 45 292.945 1.711 46
192.71934.643 SiO2 471452.820 15.000 The value corresponding to conditions in the 1st example is shown below.

(1) $1/\beta M = 0.062$ (2) $L1 / f_{\text{two}} = 1.842$ (three) $\beta_{\text{two}} / \beta = 0.10$ (four) $D_{\text{one}} / fM = 0.45$ (five) $D_{\text{two}} - NA/f_{\text{two}} = 1.37$ (six) $(\phi - B_{\text{one}}) / (2 - 4 - dW - NA) = 3.03$ -- drawing 3 -- the transverse aberration Fig. of the 1st example -- being shown -- . Here, it is drawing 3 (a). It is a transverse aberration Fig. in one hundred percent (15.3mm of image quantities) of image quantities, and is drawing 3 (b). It is a transverse aberration Fig. in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 3 (c). It is a transverse aberration Fig. in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transverse aberration Fig., a continuous line expresses the aberration curve in criteria wavelength ($\lambda = 193.4\text{nm}$), an aberration curve [in / in a dotted line / $\lambda = 193.5\text{nm}$ wavelength], an aberration curve [in / in an alternate long and short dash line / the wavelength of $\lambda = 193.45\text{nm}$], an aberration curve [in / in a broken line / $\lambda = 193.35\text{nm}$], and a two-dot chain line express the aberration curve in $\lambda = 193.3\text{nm}$ wavelength, respectively. Each transverse aberration Fig. shown in drawing 3 shows that the cata-dioptric system by this example has the image formation engine performance of $NA=0.6$ which the chromatic-aberration amendment by $193.4\text{nm} \times 0.1\text{nm}$ is especially made by amending aberration good in spite of having attained NA numerical aperture very much, and was excellent. Next, the 2nd example by this invention is explained with reference to drawing 4 $R > 4$. Drawing 4 is the optical-path Fig. showing the configuration of the cata-dioptric system by the 2nd example of this invention.

[0031] Since the fundamental configuration of the cata-dioptric system of drawing 4 is almost the same as the cata-dioptric system of the 1st example shown in drawing 1, it omits explanation here and explains only the lens configuration of each lens group. It sets to drawing 4 and is the 1st lens group G1. Negative lens component L1a of a meniscus configuration which turned the convex to the body side sequentially from the body side, Positive lens component L1b of both the convex configuration, and positive lens component L1c of both the convex configuration, It consists of positive lens component L1e of a meniscus configuration which turned the concave surface to the negative lens component L1d and body side of both the concave configuration, negative lens component L1f of both the concave configuration, and negative lens component L1g of the meniscus configuration where the convex was turned to the body side.

[0032] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration, and negative lens component L2c of both the concave configuration, As well as positive lens component L2d of both the convex configuration, positive lens component L2e of both the convex configuration, Positive lens component L2f of the meniscus configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2g of both the convex configuration where the strong convex was turned by the aperture-diaphragm AS side, Negative lens component L2h of the meniscus configuration where the convex was turned to the aperture-diaphragm AS side, Positive lens component L2i of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, It consists of negative lens component L2j of both the concave configuration which turned the strong concave surface by Wafer W side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l of the meniscus configuration where the convex was similarly turned to the aperture-diaphragm AS side. The value of the item of this example hangs up over following Table 2. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this like the 1st example of the above, and the numerical aperture NA by the side of Wafer W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And as for the cata-dioptric system of this example, the image quantity from the optical axis Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm like the 1st example of the above. Moreover, the beam splitter BS in this example is a 170mmx170mmx190mm rectangular parallelepiped configuration.

[0033] Moreover, in Table 2, the sequence of going to the 2nd page equivalent to the Wth page of the wafer as the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r , Spacing d , and the ** material of each side. All over Table 2, between Reticle and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a

convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optical paths for negative according to the optical path which reaches the directional change side of a beam splitter BS from a concave mirror M. And it is CaF₂ as ** material. Fluorite and SiO₂ Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of Ar¹ laser: $\lambda = 193.4\text{nm}$) of quartz glass and fluorite is as follows.

Quartz glass: 1.56019 fluorite : 1.50138 [0034]

[Table 2] [The 2nd example]

d0 = 111.403 r d ** material 1 5471.605 15.000 CaF₂ 2 272.290 2.678 3 277.567 31.750 SiO₂ 4 - 278.590 0.500 5 307.964 38.658 SiO₂ 6 - 321.548 0.500 7 - 307.926 28.172 CaF₂ 8 185.540 116.871 9 -6054.190 45.000 SiO₂ 10 - 326.561 3.925 11 - 437.618 18.547 CaF₂ 12 429.454 3.774 13 791.303 28.999 CaF₂ 14 197.545 13.348 15 0.000 170.000 SiO₂ Beam splitter BS16 0.000 10.000 17 -600.094 -10.000 The lieberkuhl M18 0.000 -85.000 SiO₂ 19 0.000 85.000 SiO₂ The directional change side 20 0.000 5.000 21 0.000 18.267 Aperture-diaphragm AS22 - 228.968 15.000 SiO₂ 23 602.629 1.000 24 596.556 39.120 CaF₂ 25 -193.759 0.500 26 -198.735 15.599 SiO₂ 27 414.383 1.371 28 466.129 43.827 CaF₂ 29 -250.352 0.500 30 607.920 26.660 CaF₂ 31 -570.532 0.500 32 319.703 24.752 CaF₂ 33 5248.170 0.500 34 150.926 44.958 CaF₂ 35 -11154.640 0.500 36 6931.942 15.000 SiO₂ 37 324.944 0.500 38 123.172 38.693 CaF₂ 39 27743.950 0.506 40 -22043.850 15.000 SiO₂ 41 73.840 8.552 42 103.200 33.698 CaF₂ 43 346.408 1.818 44 217.213 33.291 SiO₂ 45 1371.742 15.000

The value corresponding to conditions in the 2nd example is shown below.

(1) $1/\beta_M = -0.077$ (2) $L1 / -f - \text{two} = -1.924$ (three) $\beta - \text{two} / -\beta = -0.13$ (four) $D - \text{one} / -f_M = -0.41$ (five) $D - \text{two} - NA/f - \text{two} = -1.31$ (six) $(\phi - B - \text{one} / -\text{two} - \text{four} - dW - NA) / (f_2 \text{ and } 2) = -3.09$ — drawing 5 — the transverse aberration Fig. of the 2nd example — being shown —. Here, it is drawing 5 (a). It is a transverse aberration Fig. in one hundred percent (15.3mm of image quantities) of image quantities, and is drawing 5 (b). It is a transverse aberration Fig. in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 5 (c). It is a transverse aberration Fig. in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transverse aberration Fig., a continuous line expresses the aberration curve in criteria wavelength ($\lambda = 193.4\text{nm}$), and an aberration curve [in / in a dotted line / $\lambda = 193.5\text{nm}$ wavelength], an aberration curve [in / in an alternate long and short dash line / the wavelength of $\lambda = 193.45\text{nm}$], an aberration curve [in / in a broken line / $\lambda = 193.35\text{nm}$], and a two-dot chain line express the aberration curve in $\lambda = 193.3\text{nm}$ wavelength, respectively. Each transverse aberration Fig. shown in drawing 5 shows that the cata-dioptric system by this example has the image formation engine performance of $NA=0.6$ which the chromatic-aberration amendment by $193.4\text{nm} \times 0.1\text{nm}$ is especially made by amending aberration good in spite of having attained by numerical aperture very much, and was excellent. Next, the 3rd example by this invention is explained with reference to drawing 6 R> 6. Drawing 6 is the optical-path Fig. showing the configuration of the cata-dioptric system by the 2nd example of this invention.

[0035] Since the fundamental configuration of the cata-dioptric system of drawing 6 is almost the same as the cata-dioptric system of the 1st example shown in drawing 1, it omits explanation here and explains only the lens configuration of each lens group. It sets to drawing 6 and is the 1st lens group G1. Positive lens component L1a of both the convex configuration which turned the convex strong against a beam splitter BS side sequentially from the body side, Negative lens component L1b of both the concave configuration, and positive lens component L1c of both the convex configuration, Positive lens component L1e of a meniscus configuration which turned the convex to the negative lens component L1d and body side of the meniscus configuration where the convex was turned to the body side, It consists of positive lens component L1f of the meniscus configuration where the concave surface was turned to the body side, negative lens component L1g of both the concave configuration, and negative lens component L1h of the meniscus configuration where the convex was turned to the body side.

[0036] Moreover, the 2nd lens group G2 Sequentially from the aperture-diaphragm AS side, negative lens component L2a of both the concave configuration, Positive lens component L2b of both the convex configuration where the convex strong against an image side was turned, and negative lens component L2c of both the concave configuration, Positive lens component L2e of both the convex configuration which turned the convex strong against the positive lens component L2d and aperture-diaphragm AS side of both the convex

configuration where the convex strong against an image side was turned, Positive lens component L2f of both the convex configuration where the same convex strong against the aperture-diaphragm AS side was turned, Positive lens component L2g of both the convex configuration where the same convex strong against the aperture-diaphragm AS side was turned, Positive lens component L2i of both the convex configuration which turned the convex strong against the negative lens component L2h and aperture-diaphragm AS side of both the concave configuration where the concave surface strong against an image side was turned, It consists of negative lens component L2j of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, positive lens component L2k of a meniscus configuration which turned the convex to the aperture-diaphragm AS side, and positive lens component L2l. of the meniscus configuration where the convex was similarly turned to the aperture-diaphragm AS side.

[0037] The value of the item of this example hangs up over following Table 3. In this example, it is 1/4 time (contraction) the scale factor of the whole system of this like the 1st example of the above, and the numerical aperture NA by the side of Wafer W is 0.6, and the working distance by the side of Wafer W is 15.0mm. And for the cata-dioptric system of this example, the image quantity from the optical axis Ax on Wafer W has the exposure field of the shape of a 30mmx6mm slit in the range to 15.3mm like the 1st example of the above. Moreover, the beam splitter BS in this example is a 170mmx170mmx190mm rectangular parallelepiped configuration.

[0038] Moreover, in Table 3, the sequence of going to the 2nd page equivalent to the Wth page of the wafer as the image surface from the 1st page equivalent to the pattern formation side of the reticle R as a body side shows the radius of curvature r, Spacing d, and the ** material of each side. All over Table 3, between Reticle and the concave mirror M, the sign of the radius of curvature r of each field makes forward the case where a convex is turned at Reticle R side, and makes forward the case where a convex is turned at a beam splitter BS side, between the beam splitter BS and Wafer W. Moreover, the sign of Spacing d is just taken by other optical paths for negative according to the optical path which reaches the directional change side of a beam splitter BS from a concave mirror M. And it is CaF2 as ** material. Fluorite and SiO2 Quartz glass is expressed, respectively. Here, the refractive index in the criteria-for-use-of-food-additives wavelength (wavelength of Ar laser: $\lambda = 193.4\text{nm}$) of quartz glass and fluorite is as follows. Quartz glass: 1.56019 fluorite : 1.50138

[0039]

[Table 3] [The 3rd example]

d0 = 96.384 r d ** material 1 1566.352 33.601 SiO2 2 - 258.445 42.686 3 - 303.358 35.000 CaF2 4 254.513 39.688 5 408.129 35.000 SiO2 6 - 292.562 0.500 7 238.980 28.106 SiO2 8 177.718 35.520 9 236.585 35.000 SiO2 10 258.786 35.249 11 -1574.830 35.000 SiO2 12 - 195.650 0.500 13 -220.429 25.000 CaF2 14 228.713 7.071 15 380.419 35.000 SiO2 16 274.848 10.847 17 0.000 170.000 SiO2 Beam splitter BS 18 0.000 10.000 19 644.053 -10.000 The lieberkuhn M20 0.000-85.000 SiO2 21 0.000 85.000 SiO2 Directional change side 22 0.000 10.000 23 0.000 16.475 Aperture-diaphragm AS 24 -240.493 27.541 SiO2 25 609.289 0.500 26 648.361 39.879 CaF2 27 -161.540 0.500 28 - 161.204 15.000 SiO2 29 432.174 2.340 30 513.767 39.791 CaF2 31 - 245.896 0.500 32 397.672 35.000 CaF2 33 -1373.400 0.500 34 350.822 28.205 CaF2 35 -1504.430 0.500 36 152.096 44.808 CaF2 37 -3015.120 0.546 38 -3831.930 15.302 SiO2 39 292.927 0.657 40 122.588 34.934 CaF2 41 1224.997 0.539 42 1218.161 15.188 SiO2 43 74.562 8.605 44 108.074 35.000 SiO2 45 377.013 1.406 46 259.877 35.000 SiO2 47 767.722 15.000 The value corresponding to conditions in the 3rd example is shown below.

(1) $1/\beta_M = -0.116$ (2) $L1 / f_{\text{two}} = -2.053$ (three) $\beta_{\text{two}} / \beta = -0.18$ (four) $D_{\text{one}} / f_M = -0.40$ (five) $D_{\text{two}} - NA / f_{\text{two}} = -1.37$ (six) $-\phi_B$ (one) $/ f_{\text{two}} - f_{\text{four}} - dW - NA$ (two) $/ (f_2 \text{ and } 2) = -3.07$ -- drawing 7 -- the transverse aberration Fig. of the 3rd example -- being shown -- . Here, it is drawing 7 (a). It is a transverse aberration Fig. in one hundred percent (15.3mm of image quantities) of image quantities, and is drawing 7 (b). It is a transverse aberration Fig. in 50 percent (7.65mm of image quantities) of image quantities, and is drawing 7 (c). It is a transverse aberration Fig. in 0 percent (on an optical axis: 0.0mm of image quantities) of image quantities. In addition, in each transverse aberration Fig., a continuous line expresses the aberration curve in criteria wavelength ($\lambda = 193.4\text{nm}$), and an aberration curve [in / in a dotted line / $\lambda = 193.5\text{nm}$ wavelength], an aberration curve [in / in an alternate long and short dash line / the wavelength of $\lambda = 193.45\text{nm}$], an aberration curve [in / in a broken line / $\lambda = 193.35\text{nm}$], and a two-dot chain line express the aberration curve in $\lambda = 193.3$

nm wavelength, respectively. Each transverse aberration Fig. shown in drawing 7 shows that the cata-dioptric system by this example has the image formation engine performance of $NA=0.6$ which the chromatic-aberratic amendment by $193.4\text{nm} \times 0.1\text{nm}$ is especially made by amending aberration good in spite of having attained a numerical aperture very much, and was excellent.

[0040] In addition, as for the directional change side of a beam splitter BS, in each above-mentioned example, is desirable that it is the polarization separation side which consists for example, of dielectric multilayers. At this time, $\lambda/4$ plate is formed on the field which counters the concave mirror M of a beam splitter BS. Moreover, when aberration occurs in the above-mentioned dielectric multilayers, it is the 1st lens group G1 of beam splitter BS. The field which counters, the field which counters a concave mirror M side, and the 2nd lens group G2 It is desirable to prepare the thin film which negates the aberration of the fields which counter generated in dielectric multilayers on the whole surface at least. What is necessary is just to use the thing of a configuration of that thickness differs from a refractive index partially, for example as such a thin film.

[0041] moreover, each above-mentioned example -- setting -- the 1st lens group G1 from -- the flux of light which faces to a concave mirror M -- the directional change side of a beam splitter BS -- penetrating -- and a concave mirror M to the 2nd lens group G2 Although the going flux of light is the configuration reflected in respect of directional change of a beam splitter BS the 1st lens group G1 from -- the flux of light is reflected in respect of directional change of a beam splitter BS, and it leads to a concave mirror M, and the directional change side of a beam splitter BS is penetrated for the flux of light from a concave mirror M -- making -- the 2nd lens group G2 Also as a configuration to draw, it is equivalent on an optical design.

[0042]

[Effect of the Invention] As above, according to this invention, a big numerical aperture can be attained, and sufficient image side working distance can be secured to an image side, the miniaturization of a beam splitter can be attained further, and resolving of a quarter micron unit can be attained.

[Translation done.]

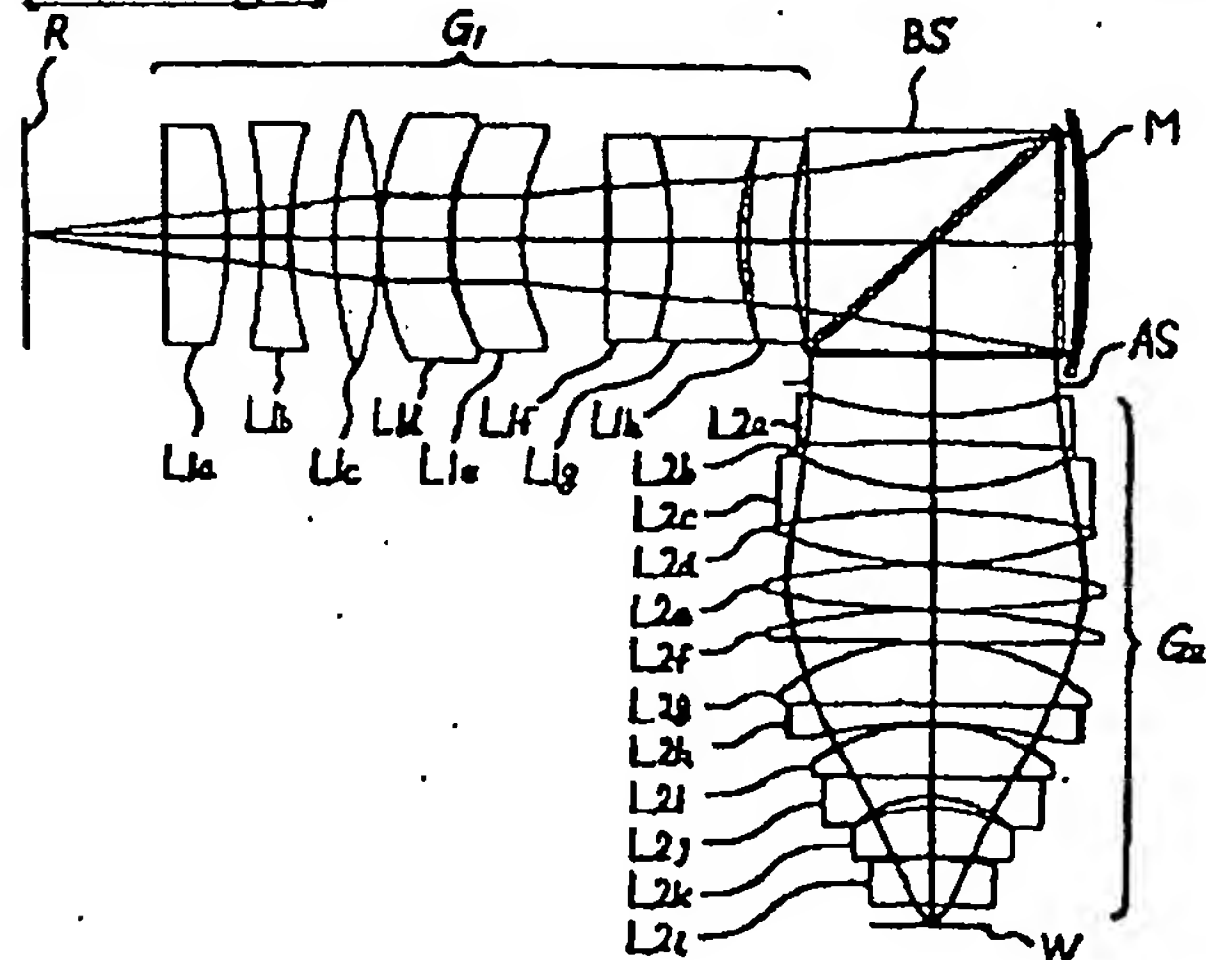
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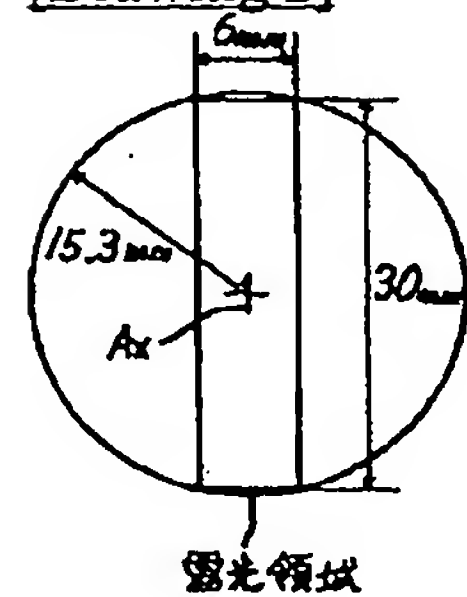
1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

DRAWINGS

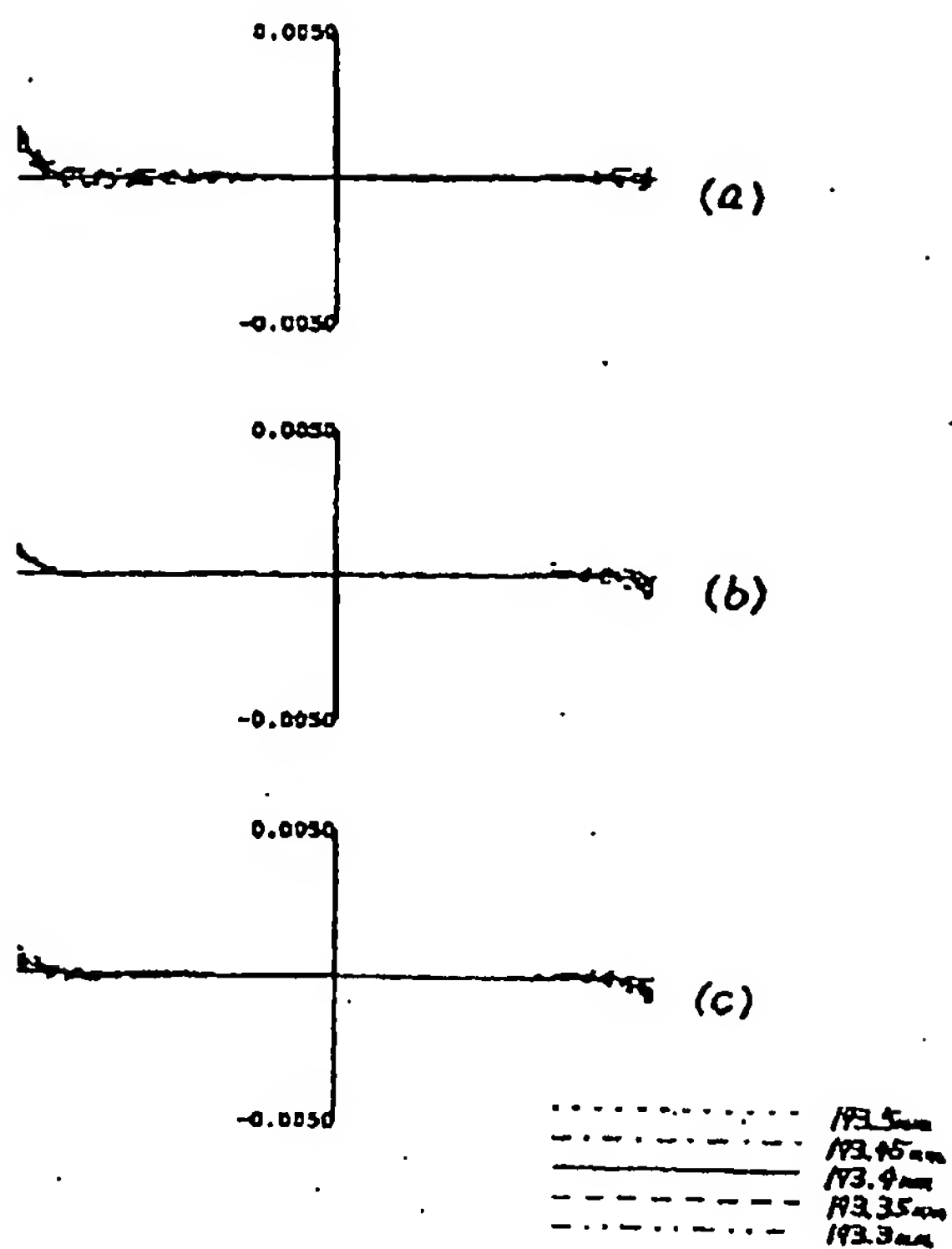
[Drawing 1]



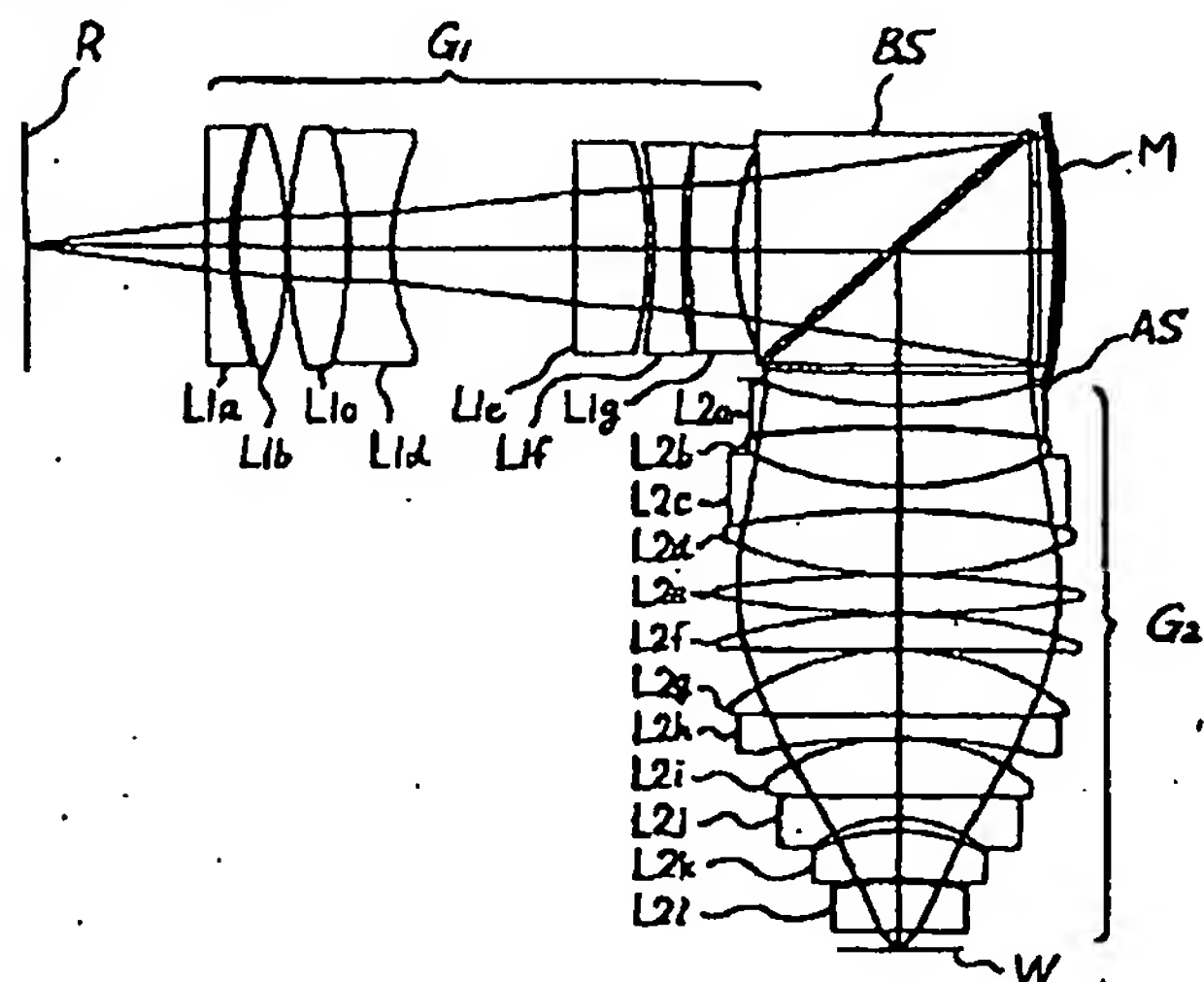
[Drawing 2]



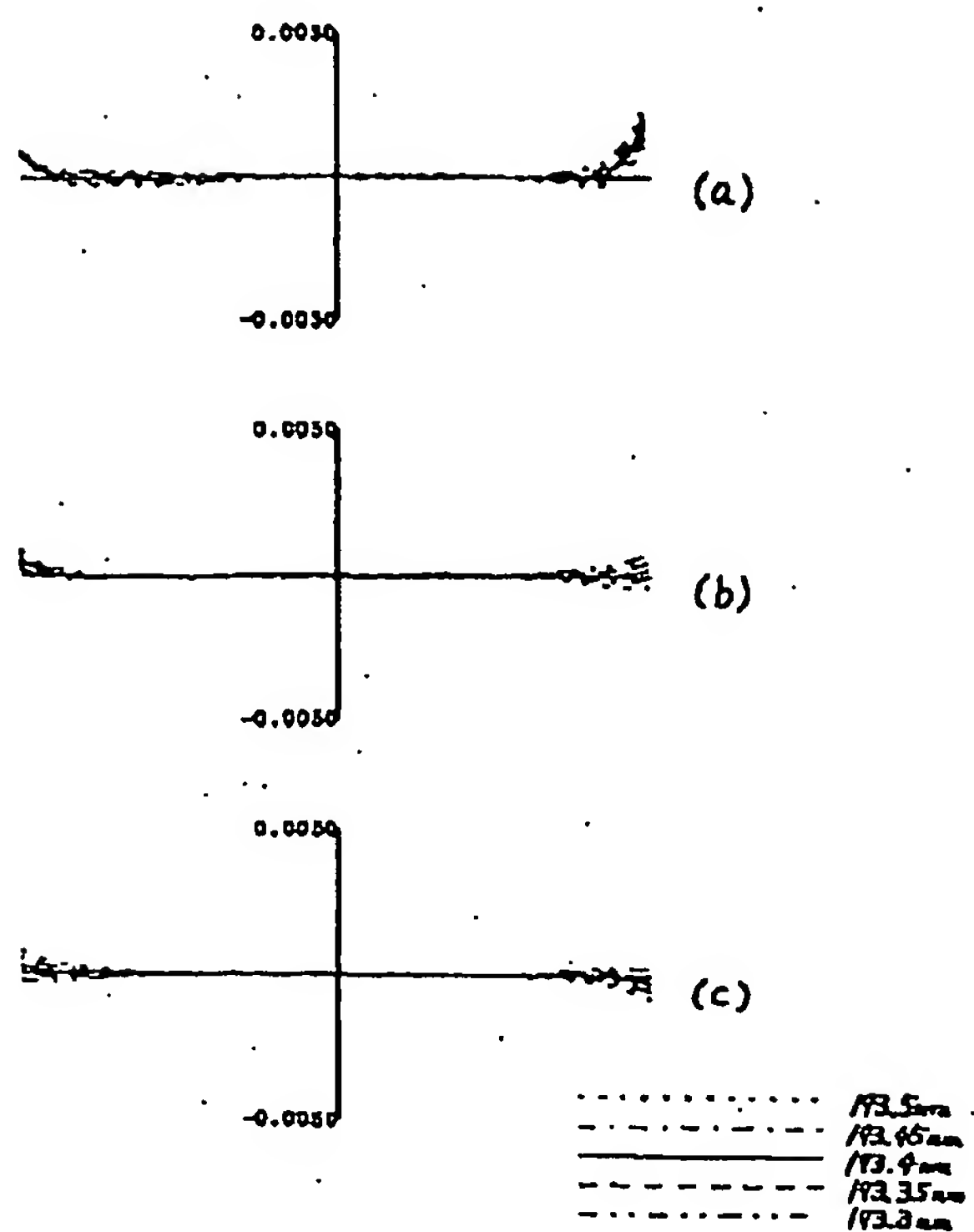
[Drawing 3]



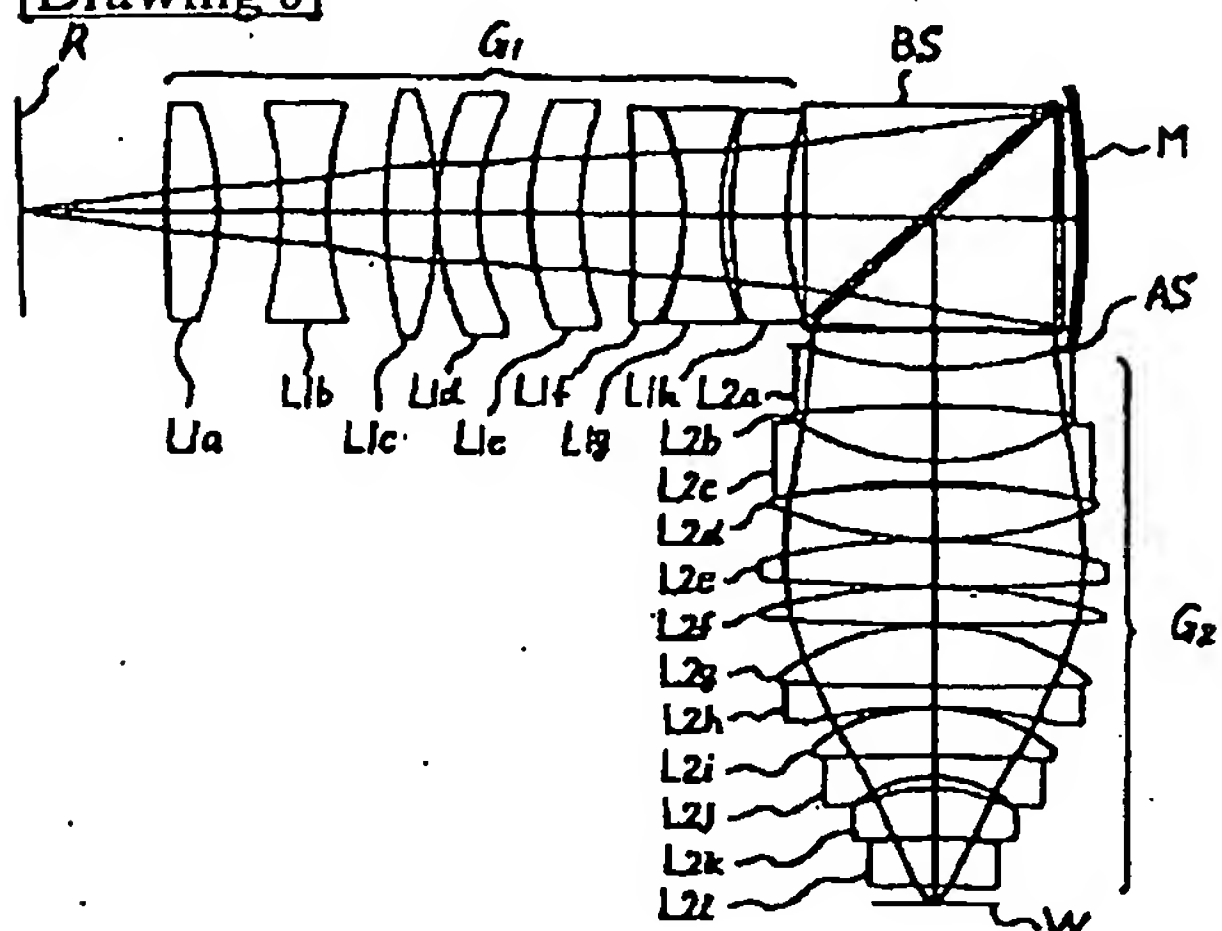
[Drawing 4]



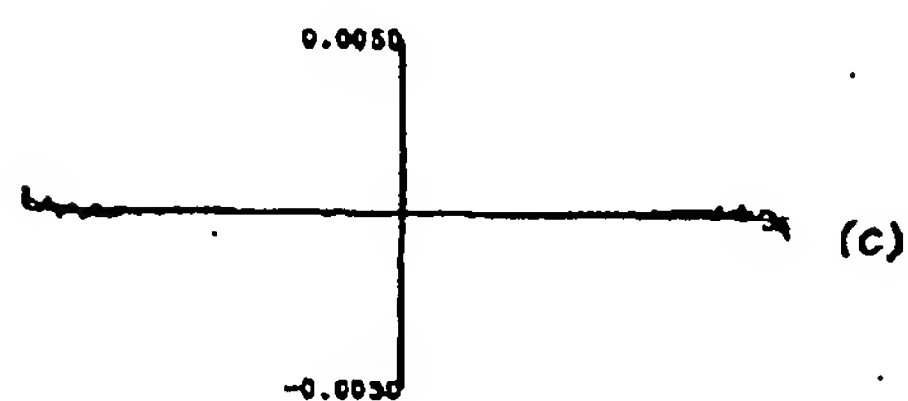
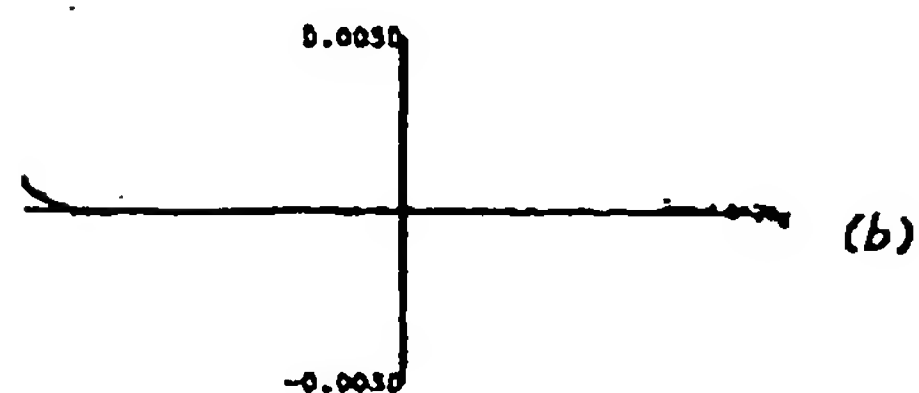
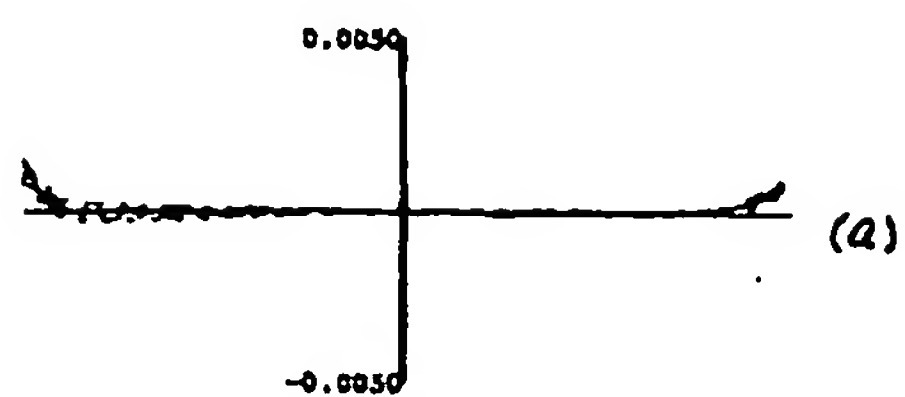
[Drawing 5]



[Drawing 6]



[Drawing 7]



.....	173.5 mm
.....	173.45 mm
.....	173.4 mm
.....	173.35 mm
.....	173.3 mm

[Translation done.]